Management of Complicated Vitreoretinal Diseases

Fabio Patelli
Stanislao Rizzo
Editors

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Editors
Fabio Patelli
Department of Ophthalmology
San Paolo Hospital
University of Milan
Milano, Italy

Stanislao Rizzo
Department of Ophthalmology
Azienda Ospedaliero
Universitaria Careggi
Florence, Italy

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Preface

Vitreoretinal surgery is the most fashinating and complex surgery in ophthalmology field.

In everyday practice the surgeon constantly faces vitreoretinal complex cases and intra and postoperative complications, unpredictable. This book was created with the idea of giving advice and guidance on how to treat and manage these situations. To do this we gathered internationally renowned surgeons who helped in the writing of this book mainly putting their experience on surgical area.

The surgeon should be found among the pages of this book answer to everyday problems of this difficult and varied surgical branch of ophthalmology.

This would be a book to be kept in the operating room, which can be useful both for young surgeons who for the most experienced surgeons.

Only through experience and mistakes you can get good results and win battles were defeats, giving hope to those who fell into obscurity.

Milan, Italy — Fabio Patelli
Pisa, Italy — Stanislao Rizzo

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Macular Buckling Technique in High Myopia

1

Micol Alkabes, Claudia Quijano, and Carlos Mateo

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M. Alkabes, MD (✉)
San Giuseppe Hospital, University Eye Clinic, Via San Vittore, 12, Milan 20123, Italy

IMO – Instituto de Microcirugia Ocular, Barcelona, Spain
e-mail: micol_alkabes@hotmail.com

C. Quijano • C. Mateo
IMO – Instituto de Microcirugia Ocular, Barcelona, Spain
e-mail: claudiaquijano@hotmail.com; carlosmateo@me.com

1.1 Introduction

High myopia is related to eye elongation and a refractive error of at least −6.00 D or an axial length greater than 26.5 mm. Excessive axial elongation of the globe can cause mechanical stretching of the ocular structures accompanied by thinning of the sclera and choroid resulting in various retinal degenerative changes. It is known that these patients can also develop a posterior bulging of the eyeball called posterior staphyloma (PS) [1, 2], which may lead to serious complications such as retinal detachment secondary to a macular hole (MHRD) [3], myopic foveoschisis (MF) with or without foveal detachment [4], and myopic foveoschisis associated with a full-thickness macular hole [5–8].

Causative factors include anteroposterior traction induced by vitreous cortex and posterior staphyloma, tangential forces exerted by epiretinal membranes (ERM), internal limiting membrane (ILM), and stretched retinal vessels [9]. Thus, the term *myopic traction maculopathy* has been proposed to describe these vitreoretinal disorders secondary to high myopia [10].

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Various surgical procedures have been proposed for the treatment of staphyloma-related tractional diseases, including pars plana vitrectomy (PPV) with or without intraocular tamponade [11] and with or without internal limiting membrane (ILM) removal, scleral shortening, suprachoroidal buckling [12], and episcleral macular buckling [13–33]. For many years, pars plana vitrectomy (PPV) with intravitreal gas injection with or without ILM peeling has been preferred as a first approach to treat MHRD [34, 35] and MF [36]. However, silicone explants have been used since the 1960s [13–17], and in the last few years, this "old classic" surgical technique has started to regain popularity among vitreoretinal surgeons to treat high myopic patients. In addition, it has been progressively recognized as the only way to mechanically counteract the pulling effects of the PS.

1.1.1 The Rationale

Since tractional forces are thought to be involved in the pathogenetic mechanism of the myopic traction maculopathy, the authors believe that applying both surgical techniques, such as pars plana vitrectomy (PPV) and macular buckling (MB), together may eliminate the causes which may prevent anatomical success and functional improvement. The advantages of the combination of these procedures are as follows: firstly, adding MB to PPV may counteract and further invert the inner forces of the stretched retinal vessels in the area of the staphyloma and release the tangential tractional forces which could not be reduced with PPV alone; secondly, there is no need for transscleral drainage, which avoids possible complications such as perforation of the globe or choroidal detachment as reported in cases of episcleral buckling alone [19, 20, 23, 25]; and thirdly, even if it takes significant more time than MB alone, PPV allows the performance of some important maneuvers which will be discussed further in the text.

1.1.2 Surgical Indications

Despite MB and PPV being used primarily in cases of MHRD [13–27, 29, 33], several authors have also described the combined approach to be safe and effective and reported positive outcomes in myopic tractional retinoschisis alone or associated with a full-thickness macular hole [28, 30–32, 36].

The three main conditions where the technique may be useful are:

1. *Retinal detachment secondary to macular hole* (*MHRD*) [13–27, 29, 33] (Fig. 1.1).
2. *Macular hole with myopic foveoschisis* (*MH and MFS*) [32, 33] (Fig. 1.2).
3. *Myopic foveoschisis* (*MFS*) *with foveal detachment* [28, 30, 32, 33]. In this last condition, the episcleral approach might be suggested in case of a thin "roof" in the area of foveal detachment to avoid the risk of inducing a full-thickness MH with PPV and ILM peeling (Fig. 1.3).

1.2 Surgical Technique

1.2.1 Choice of Macular Buckle: Personal Experience

Different types of episcleral posterior buckles have been described in the literature [13–17, 24, 25, 28, 29]. However, our personal experience is mostly focused on three of them.

- A *silicone band* (6 mm in width), usually used as an encircling buckle, was chosen as the first indenting device in all patients who underwent surgery prior to 2009.
- The *Ando plombe* consists of a semitransparent T-shaped silicone rod embedded with titanium wires to give rigidity and permit them to be bent in order to achieve the desired curvature and optimal positioning of the squared (5×5 mm) indenting head under the fovea. The other end has ridges that facilitate its fixation with sutures to the temporal sclera. Two sizes may be selected, 25 or 27 mm, according to the axial length of the eye [22, 23] (Fig. 1.4).

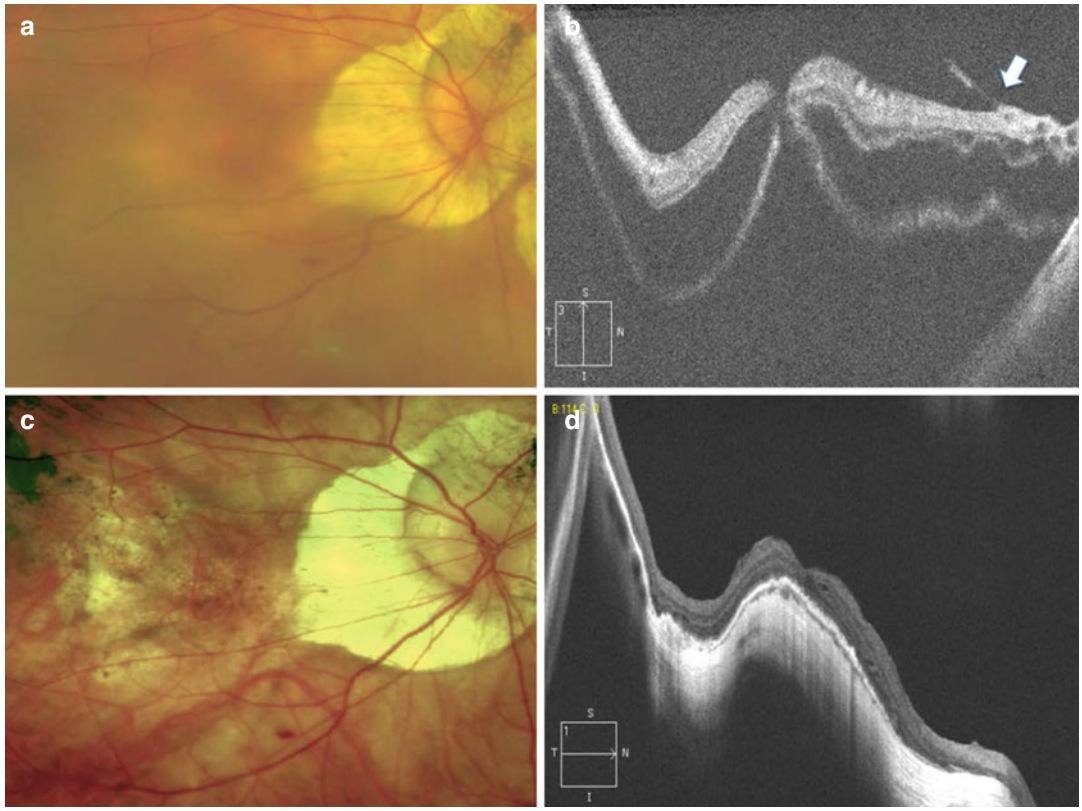

Fig. 1.1 Retinal detachment secondary to high myopic macular hole (MHRD). (**a**) Fundus photograph shows a retinal detachment in the posterior pole which extends until the temporal quadrant, but a full-thickness MH cannot be easily recognized. (**b**) Preoperative OCT scan confirms the presence of a small macular hole with remnants of an attached posterior hyaloid superiorly to the fovea (*white arrows*). (**c**) Postoperatively, the retina is completely reattached as observed on color fundus photograph and (**d**) OCT scan confirms the MH closure and the flat retina above the macular indentation. (OCT scans obtained with Cirrus HD-OCT 4000 (Carl Zeiss Meditec, Dublic, CA); IMO (Instituto de Microcirugia Ocular), Barcelona, Spain)

- The *AJL macular buckle* is made of silicone-coated polymethyl methacrylate (PMMA) and differs from the Ando plombe since it does not allow bending and has an 8 mm in diameter rounded indenting platform (Fig. 1.4).

In order to improve the positioning of the episceral device under the macular area, both the AJL macular buckle and Ando plombe may be supplied with an additional light probe as reported in a previous study [33] (Fig. 1.4).

However, according to the literature, since the surgical technique and the buckling effect of these posterior exoplants – Ando plombe (Ondeko Corporation, Tokyo, Japan) and AJL macular buckle (AJL Ophthalmic Spain) – are considered by the authors to be superior to the 6-mm silicone band, they were preferred from 2009 as episcleral indenting devices.

1.2.2 Exposure of the Appropriate Scleral Quadrant

Two different scleral approaches which do not require muscles disinsertion may be chosen depending on the type of the episceral buckle. These are for the 6-mm silicone band and Ando plombe or AJL macular buckle.

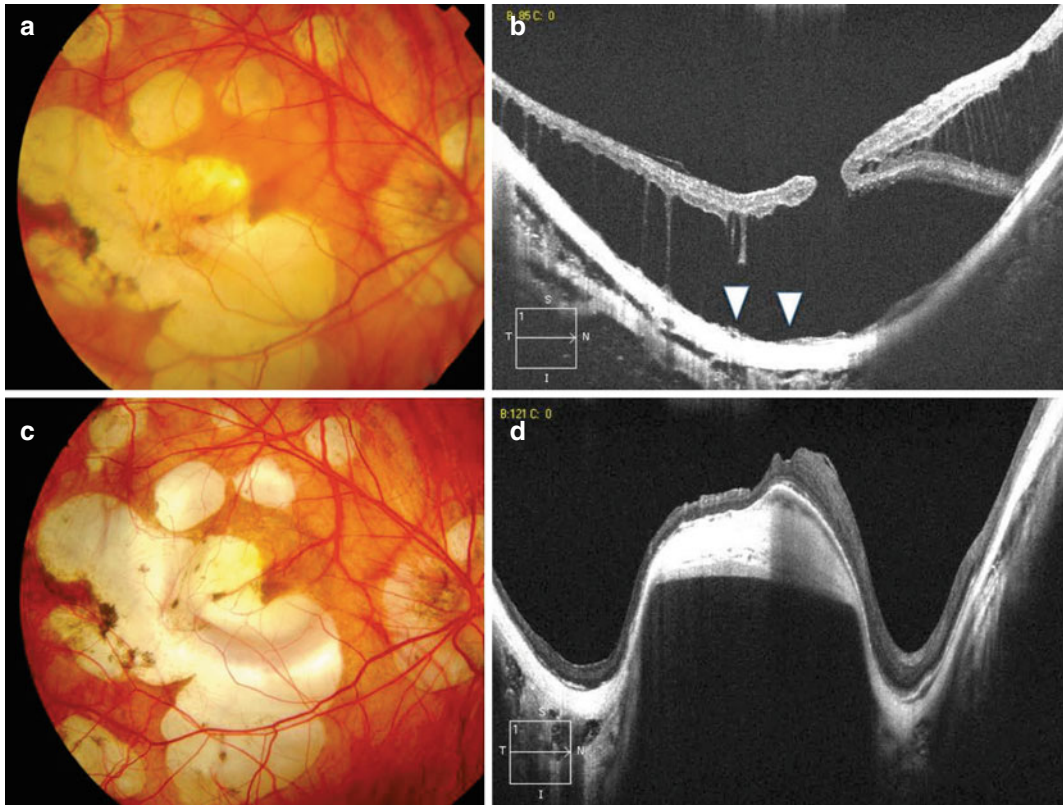

Fig. 1.2 Macular hole with myopic foveoschisis (MH and MFS). (**a**) Fundus photograph shows a shallow macular detachment, but a full-thickness MH cannot be easily recognized due to the lack of contrast which is caused by a severe chorioretinal atrophy in the macular area. (**b**) OCT scan confirms the presence of a full-thickness macular hole and a long-term retinoschisis in the temporal side corresponding to the atrophy showed on fundus photograph. Residual outer retinal layers under the retinoschisis (*arrow heads*) and a foveal detachment can also be observed. (**c**) On postoperative color fundus photograph, the scleral indentation obtained with the Ando plombe is clearly visible in the macular area where the schisis is totally resolved. (**d**) OCT scan confirms the MH closure and the flat retina above the macular indentation. Note the change of the concavity of the posterior staphyloma into a convex shape induced by the indenting buckle. (OCT scans obtained with Cirrus HD-OCT 4000 (Carl Zeiss Meditec, Dublic, CA); IMO (Instituto de Microcirugia Ocular), Barcelona, Spain)

1.2.2.1 6-mm Silicone Band

A 360° temporal conjunctival peritomy is performed with separation of the Tenon capsule. The 6-mm silicone band is placed across the macular area from the inferonasal to the superonasal scleral quadrants, after isolating the superior, inferior, and temporal and nasal rectus muscles with a 3/0 silk suture (Fig. 1.5). Special attention has to be paid to be posterior to the complete inferior oblique insertion and to avoid damage to the inferotemporal vortex veins.

The inferior end is then sutured to the sclera with a 5/0 nylon suture near the insertion of the inferior rectus muscle in the nasal quadrant. The superior end is left free in the superotemporal quadrant during vitrectomy. Once vitreous surgery has been completed and the buckling effect

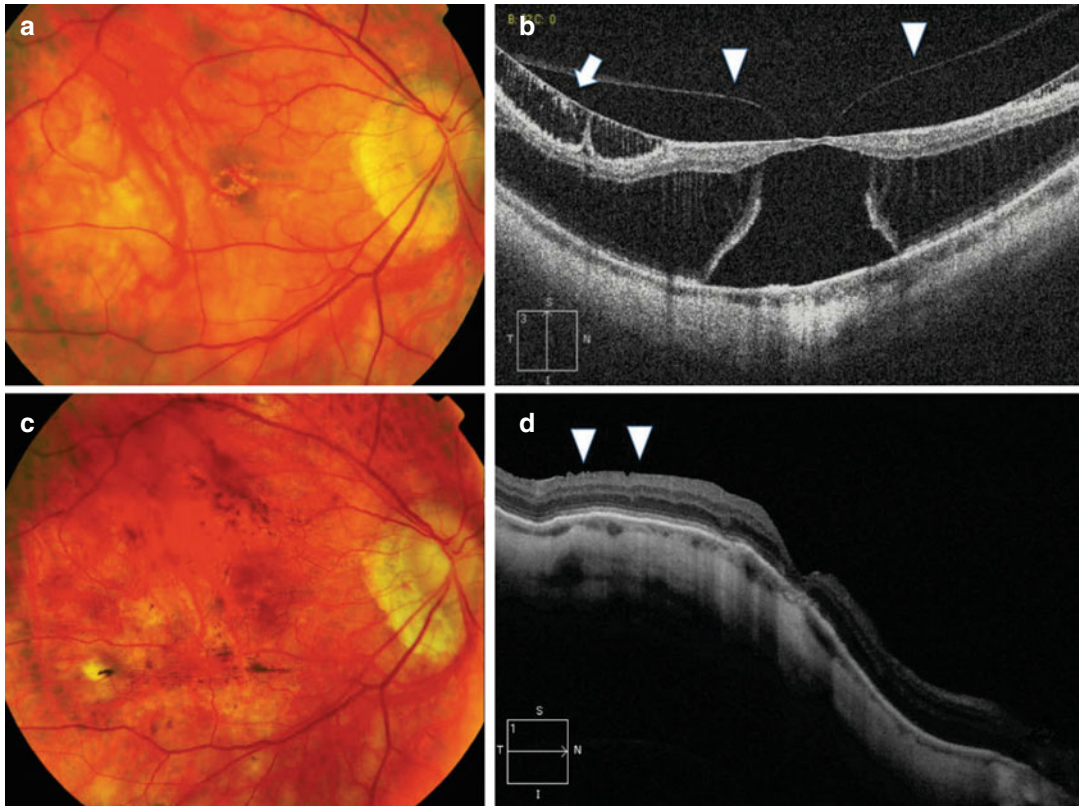

Fig. 1.3 Myopic foveoschisis (MFS) with foveal detachment. (**a**) Color fundus photograph of a high myopic patient showing an MH-like appearance. (**b**) Preoperative OCT reveals the presence of a myopic foveoschisis associated with foveal detachment. Note the hyperreflective line at the level of the inner retina (*white arrow*) which may be suggestive for an ILM detachment. An attached posterior hyaloid (*arrow heads*) is also observed on the same scan in the foveal area. (**c**) Postoperative fundus photograph shows a degree of RPE disturbance within the posterior pole, but the scleral indentation is not clearly visible. (**d**) However, SD-OCT confirms the reshaping of the posterior eye wall, the ILM peeling with inner retinal dimples (*arrow heads*), and a complete resolution of the foveoschisis. Moreover, the retina in the foveal area is totally reattached, but the loss of the IS ellipsoid band can also be observed at the level of the outer retina. (OCT scans obtained with Cirrus HD-OCT 4000 (Carl Zeiss Meditec, Dublic, CA); IMO (Instituto de Microcirugia Ocular), Barcelona, Spain)

over the macula is achieved, the superior end of the silicone band can be finally sutured to the superonasal sclera with a 5/0 nylon suture (Fig. 1.5).

1.2.2.2 Ando Plombe or AJL Macular Buckle

The superotemporal quadrant is further preferred for an easier and better placement of the buckle and with the aim of avoiding the inferior oblique muscle which runs posteriorly and laterally along the entire inferotemporal quadrant.

A 140° superotemporal conjunctival peritomy is performed with separation of the Tenon capsule. The superior and temporal rectus muscles are isolated and hooked using a 3/0 silk suture to allow a better exposure of the scleral quadrant (Fig. 1.6).

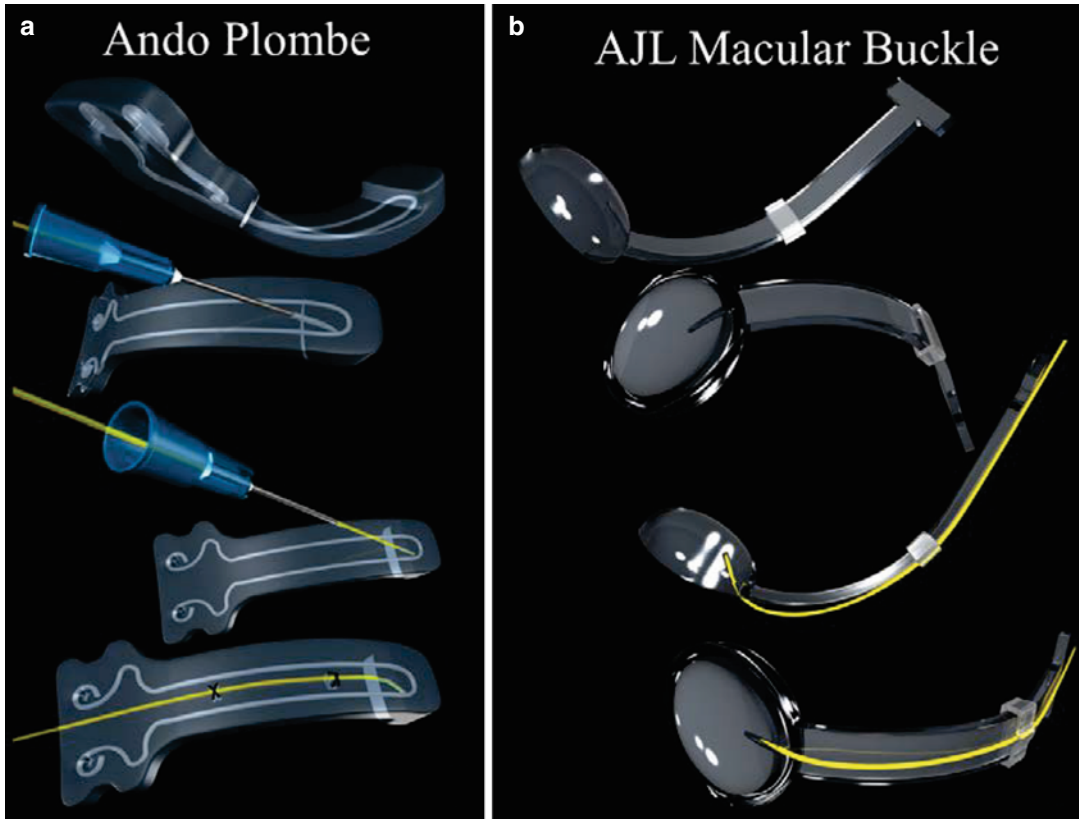

Fig. 1.4 Graphic 3D representation of two types of macular buckles with additional light probe. (**a**) The *Ando plombe* consists of a semitransparent T-shaped silicone plate embedded with titanium wires. This design provides rigidity and allows the macular buckle to be bent in order to achieve the desired curvature and optimal positioning of the squared 5×5 mm indenting platform underneath the central macula. The proximal end has ridges that allow its fixation with sutures to the superotemporal scleral quadrant. An additional 29G optic fiber can be inserted through a 23G needle shaft. This needle will guide the light probe to the center of the indenting buckle head and will allow its optimal positioning under the macular due to transillumination. (**b**) The *AJL macular buckle* is made of silicone-coated polymethyl methacrylate (PMMA). It differs from the Ando plombe as it does not bend and has a rounded, 10 mm-diameter indenting platform. A groove in the indenting platform allows insertion of an optic fiber without using additional sutures or a needle shaft to localize more accurately the center of the platform during buckle positioning under the macula. (3D graphic design realized by Alex Couto; IMO (Instituto de Microcirugia Ocular), Barcelona, Spain)

When the temporal sclera is exposed, a 5/0 nylon suture is placed in the superotemporal quadrant between the insertion of both superior and inferior oblique muscles, about 20 mm from the corneal limbus. Particular care must be taken during this step in order to avoid damage to the vortex veins located near the superior oblique's tendon (Fig. 1.7).

It is recognized that high myopia may lead to a progressive scleral thinning which may increase the risk of perforation of the eye, forcing the surgeon in some cases to look for a better location to place the initial mattress suture (Fig. 1.8). For the same reason, trying to reduce the risk of unintentional hypotony and choroidal effusion in case of scleral perforation, we preferred to apply this first nylon suture in a closed eye.

In the case of patients that have an encircling band due to a previous rhegmatogenous retinal detachment, the surgeon can place the macular buckle under the encircling silicone band and avoid its removal whenever it is possible (Fig 1.8).

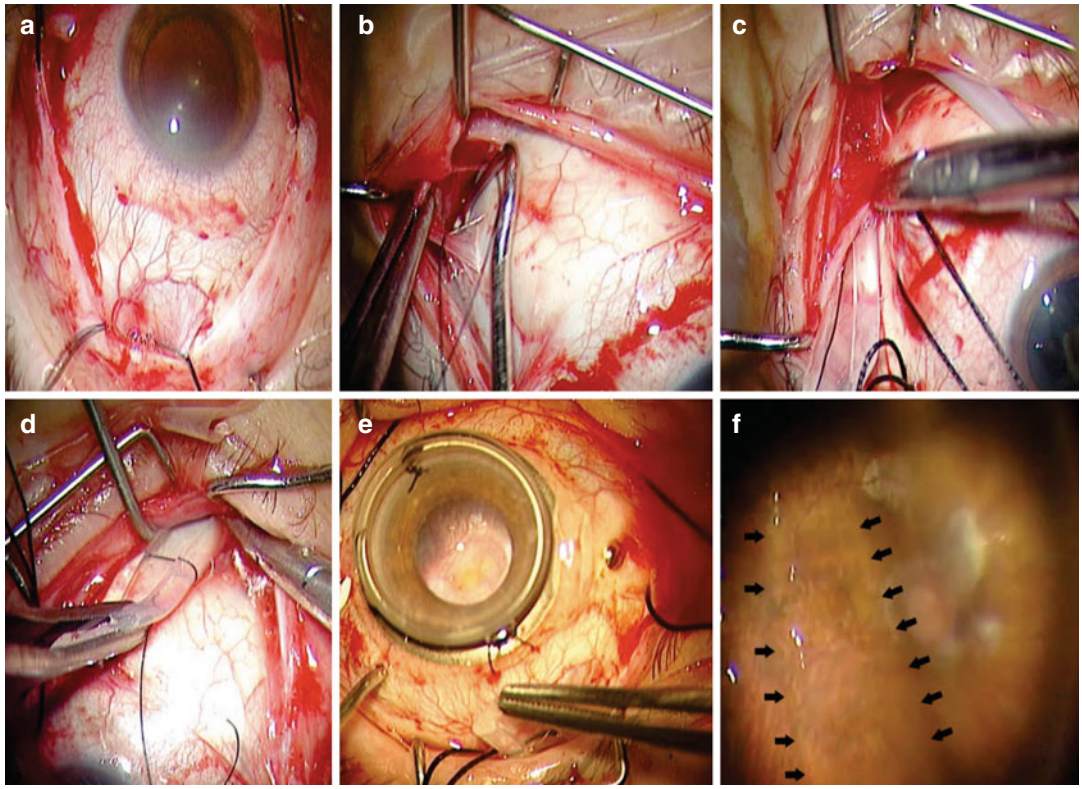

Fig. 1.5 (**a**) Using a 6-mm silicone band, a 360° peritomy is performed and the four rectus muscles are hooked with 3/0 silk sutures. (**b**) The inferior oblique tendon is then hooked. Special care must be taken to hook it completely and to avoid separation of its fibers. If this happens, the correct position of the band will be blocked, and it will go through the muscle fibers. (**c**) The inferior end is then sutured to the sclera with a 5/0 nylon suture near the insertion of the inferior rectus muscle in the nasal quadrant, pointing toward the macular area. (**e**) The superior end is left free in the superotemporal quadrant during the intraocular maneuvers. (**d**, **f**) Once vitreous surgery has been completed, the superior end needs to be pulled until the buckling effect is achieved and the silicone band can then be sutured to the superonasal sclera with a 5/0 nylon suture

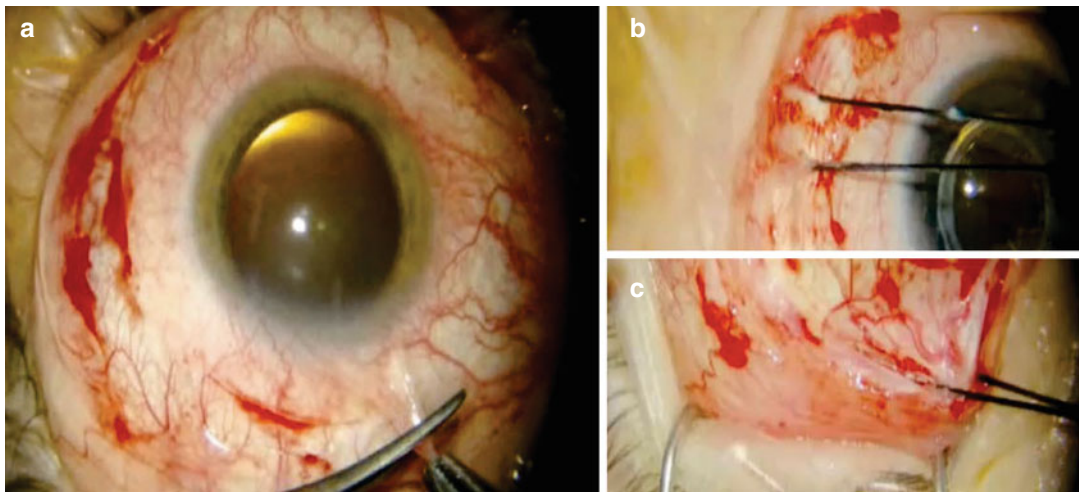

Fig. 1.6 (**a**) A 140° superotemporal conjunctival peritomy is performed with separation of the Tenon capsule. (**b**) Lateral and (**c**) superior rectus muscles are isolated and hooked using a 3/0 silk suture to allow a better exposure of the superotemporal scleral quadrant

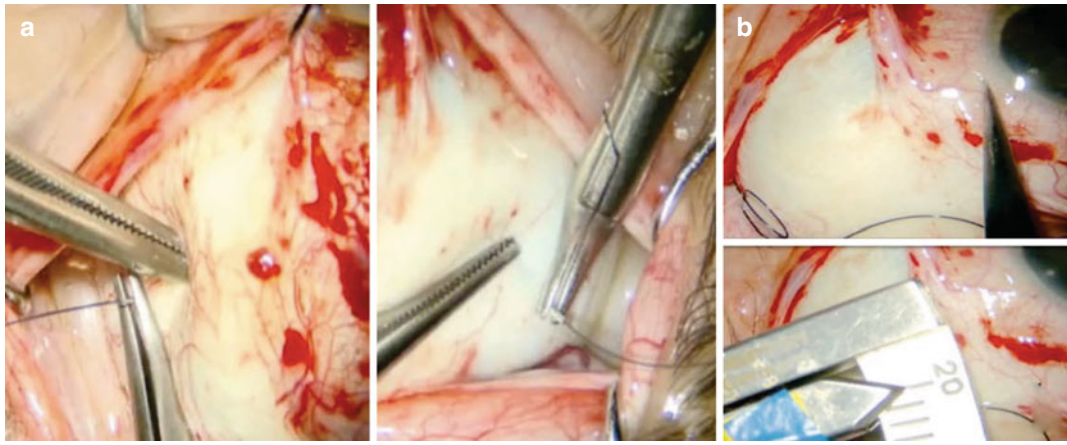

Fig. 1.7 (**a**) After exposing the temporal sclera, a 5/0 nylon suture is placed in the superotemporal quadrant at a position between the insertion of both the superior and inferior oblique muscles, about 20 mm from the corneal limbus (**b**)

1.2.3 Pars Plana Vitrectomy

Although the choice of using a 20G, 23G, 25G, or 27G system is mostly based on the surgeon's personal preference, it is crucial that any instrument chosen must be long enough to allow the operator to reach the posterior pole of the eye. This procedure can be difficult in these special cases of great axial length. If a sufficiently long instrument is used, any less invasive technique of a standard three-port PPV can be used.

Since high myopic patients tend to be younger and the posterior hyaloid tends to be degenerated and more often not completely detached, triamcinolone acetonide (TA) may be used to facilitate the posterior vitreous detachment (PVD). Depending on the surgeon's experience, the posterior hyaloid can be removed using vitreous cutter, forceps, and/or the Tano diamond-dusted scraper (Fig 1.9). In this last case, remnants of collagen's fibers can be gently peeled off from the inner retinal surface.

In case of retreatment, even after silicone oil removal, if present, PPV should be extended until the vitreous base and completed with the help of a bimanual technique and scleral indentation (Fig 1.10). Indeed, it is well known that an accurate vitreous cortex removal is a crucial factor in order to prevent surgical failure and reduce the risk of PVR [20]. Pars plana lensectomy (PPL) with sparing of the anterior capsule can be also carried out before PPV allowing a better and complete shaving of the vitreous base. Furthermore, lens removal may improve the ILM visualization during the ILM peeling procedure.

1.2.4 Dyes

Epiretinal membrane (ERM) and the ILM can be peeled off using green or blue dyes such as ICG, trypan blue, brilliant blue, or both.

To prevent the spilling or leakage of the dye from passing into the subretinal space, a small bubble of perfluorocarbon (PFC) can be injected to temporarily cover the hole in case of MHRD. As an alternative procedure, dyes can be mixed with viscoelastic making them heavier and reducing the risk of dye accumulation under the retina (Fig 1.11). This can make the fluid-air exchange or temporary closure of the infusion unnecessary.

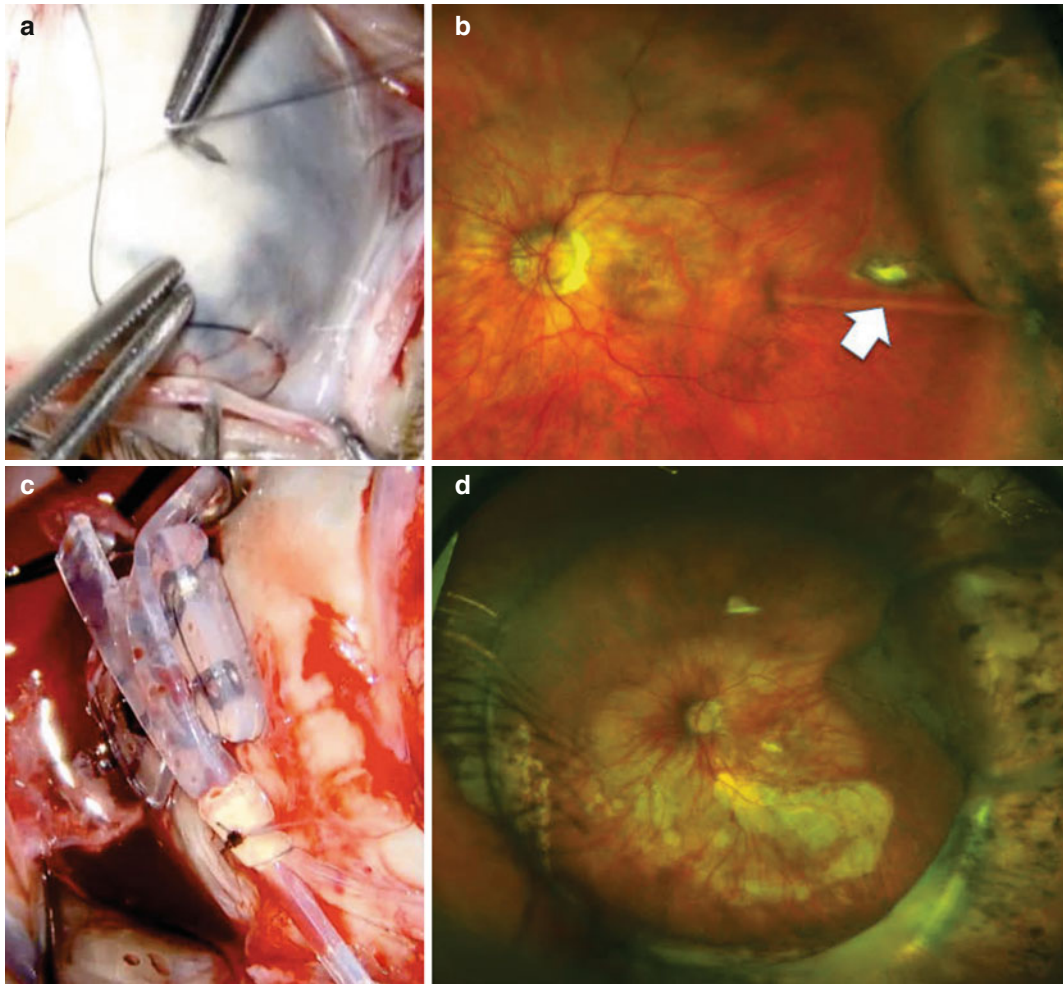

Fig. 1.8 (**a**) The first 5/0 nylon suture must be carefully placed to avoid perforation of the eye wall due to a thinner sclera. (**b**) The *arrow* shows the site of unintentional perforation during the suture's placement. (**c**, **d**) illustrates a patient with a previous encircling buckling who underwent second surgery for persistent retinal detachment secondary to a macular hole. The Ando plombe macular buckle is placed in the superotemporal quadrant under the encircling band. Both scleral indentations are visible in the postoperative wide-field fundus photograph. (Ultrawide-field color fundus photographs obtained with Optomap 200MA (Optos PLC, Dunfermline, Fife, Scotland); IMO (Instituto de Microcirugia Ocular), Barcelona, Spain)

1.2.5 Use of PFC

It is widely recognized that high myopic eyes have a thin sclera. In spite of continuous irrigation, trying to maintain the intraocular pressure (IOP) may be difficult especially when sclerotomies are performed with a 20G system and also in case of not-valved 23G or smaller trocars. This can occur when instruments are temporarily pulled out through the sclerotomies during any surgical maneuvers, with a rapid and severe decrease of the IOP. We have to be careful with these sudden changes of the IOP, because not every PPV device has an internal pressure control which avoids rapid IOP changes. In light of all these considerations, since hypotony has been considered one of the main risks of intraoperative choroidal effusion (especially in cases of a thin sclera as occurs in high myopic eyes), a PFC

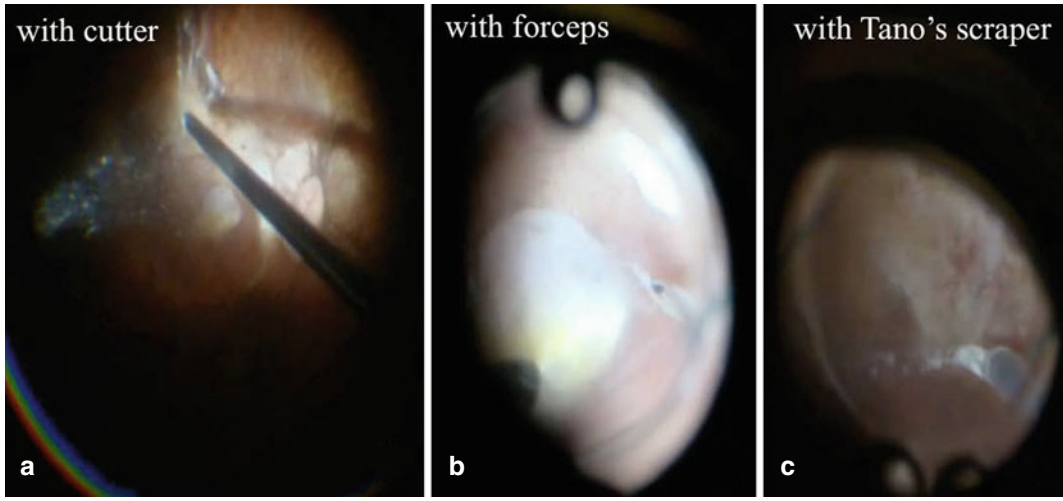

Fig. 1.9 Triamcinolone acetonide (TA) can be used to facilitate posterior vitreous detachment (PVD). The posterior hyaloid and/or remnants of vitreous cortex can be removed using (**a**) vitreous cutter, (**b**) forceps, and/or (**c**) a Tano diamond-dusted scraper

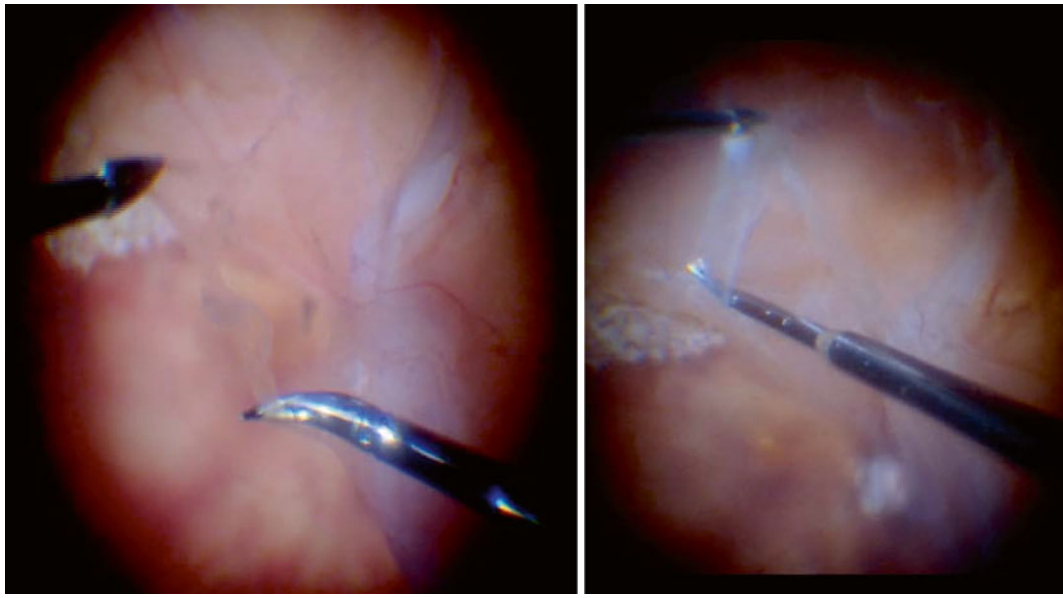

Fig. 1.10 It is recommended to perform complete pars plana vitrectomy (PPV) by accurately removing the vitreous cortex as well as removing the vitreous base. It can be completed with a bimanual technique and scleral indentation. This procedure will avoid the development of proliferative vitreoretinopathy (PVR) which is one of the significant risk factors of surgical failure

temporary tamponade may be preferred during the ERM/ILM peeling to prevent any additional risk. Thus, when most of the dye has been aspirated, PFC can be slowly injected and ERM/ILM may subsequently be removed.

In case of MHRD, another interesting advantage of using PFC is that it also displaces any subretinal fluid to the periphery. When the detachment is extended until the peripheral retinal and there is no a peripheral break, a small retinotomy can be per-

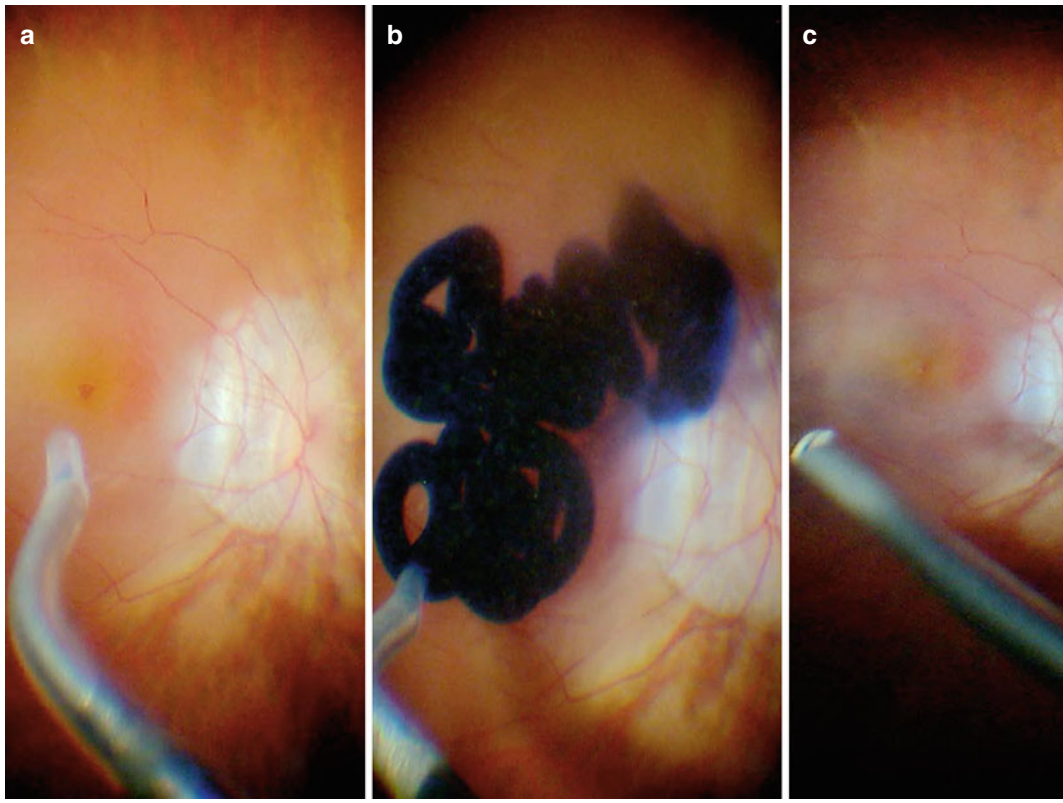

Fig. 1.11 (**a**) If there is macular hole retinal detachment (MHRD), in order to avoid the dye passing into the subretinal space, (**b**) *blue* dye can be mixed with viscoelastic. This makes the dye heavier and more viscous and reduces the risk of the dye spilling under the retina. (**c**) After the mixture of trypan blue and viscoelastic substance is removed, a stain of preretinal structures is clearly observed

formed superiorly to the horizontal meridian to drain the fluid (Fig 1.12). This also avoids the need to aspirate it through the MH reducing the risk of enlargement and trauma to the borders of the hole.

1.2.6 ILM Peeling

ILM needs to be gradually peeled off with the end-gripping forceps. We can say it is completely removed when a minimal extension of approximately two or three disk diameters 360° all around the fovea is achieved.

Making this maneuver under PFC offers several advantages. When the optic fiber is directed toward the retina, PFC creates a certain degree of reflexes and shadows from the retina, which may lead to a better visualization of the edges of the ILM removal (Fig. 1.12). This seems to be even more important in cases with a lack of contrast due to severe chorioretinal and RPE atrophy, as often happens in high myopic patients.

In case of retreated patients, restaining of the ILM can be performed, the area of the ILM peeling may be further extended, and any remnants of the ILM at the edges of the hole, if present, can be also removed.

However, special care should be given during the ILM peeling in high myopic eyes. Since the ILM seems to represent the structure which mostly contributes to the biochemical strength of the retina [37], its removal might decrease the

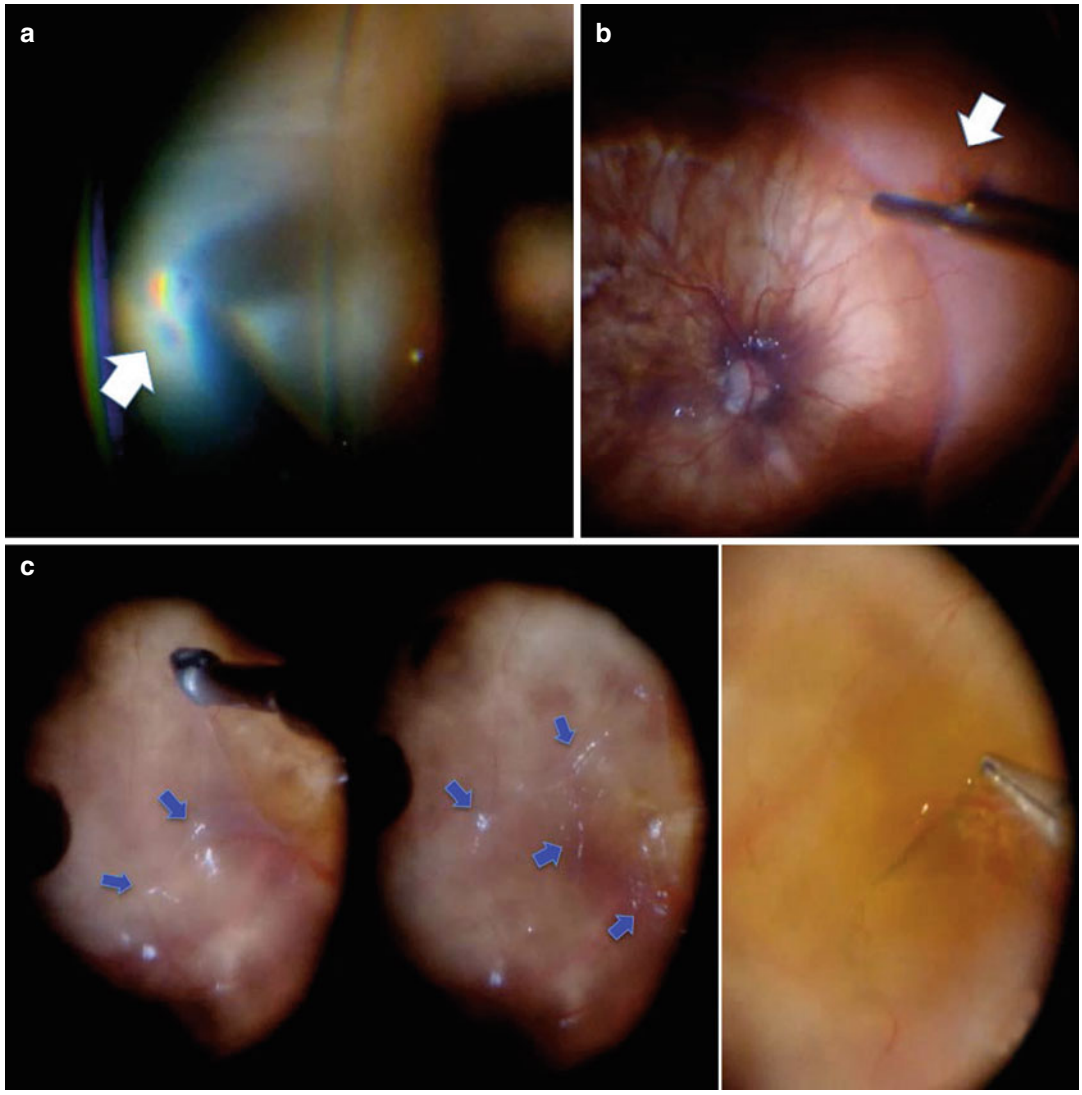

Fig. 1.12 One of the advantages offered by the use of perfluorocarbon (PFC) is that in the case of retinal detachment, it displaces the subretinal fluid to the periphery. (**a**, **b**) When the detachment is extended until the peripheral retina and there is not a peripheral break, a small retinotomy can be performed above the horizontal meridian (*white arrows*). The fluid can be finally drained through this retinotomy, avoiding the need to drain it through the MH and reducing the risk of hole enlargement. (**c**) PFC temporary tamponade is usually preferred during the ERM/ILM peeling – because when the optic fiber is directed toward the retina, the PFC creates reflections and shadows from the retina (*blue arrows*), which may lead to a better visualization of the edges of the ILM removal, even after the use of dyes. This seems to be even more important in cases with a lack of contrast due to a severe chorioretinal and RPE atrophy, as frequently happens in highly myopic patients

retinal strength. As a consequence, this relative weakness might finally predispose more easily to central retinal tears, as demonstrated by the postoperative appearance of non-foveal MHs [38–40] with an increased risk of retinal redetachment in contrast to emmetropic eyes.

1.2.7 Placement of the Macular Buckle

Before placing the buckle, a 29G optic fiber, which can be switched on when necessary, has to be inserted toward the center of the indenting

platform as shown in Fig. 1.13. The light offers the advantage of a better and easier correct placement exactly under the macular region via transillumination. In cases of the Ando plombe, it must be guided through a 23G needle that can be finally removed allowing the optic fiber's fixation to the plombe with two 5/0 nylon sutures.

Once PPV is completed, maintaining PFC into the vitreous cavity and closing the sclerotomies with temporary stainless steel plugs to avoid hypotony, the illuminated macular plombe is inserted in the superotemporal quadrant guided and across the previously placed 5/0 nylon scleral suture and held in place. When inserting the plombe, special care needs to be taken to avoid lesions of the optic nerve and the vascular structures at the posterior pole. When the positioning of the illuminated macular buckle is correct and the indentation is perfectly centered at the fovea (Fig. 1.14), the proximal end of the plombe is fixated with additional 5/0 nylon scleral sutures (Fig. 1.15) and the internal light is removed.

1.2.8 Completion of the Surgery and Postoperative Period

When the procedure is finished, the peripheral retina must be examined in case there is a break or hole which may require laser treatment. This appears more frequently in highly myopic eyes because of their tendency to previously have or develop during surgery retinal holes adjacent to the vascular structures or next to the atrophic areas.

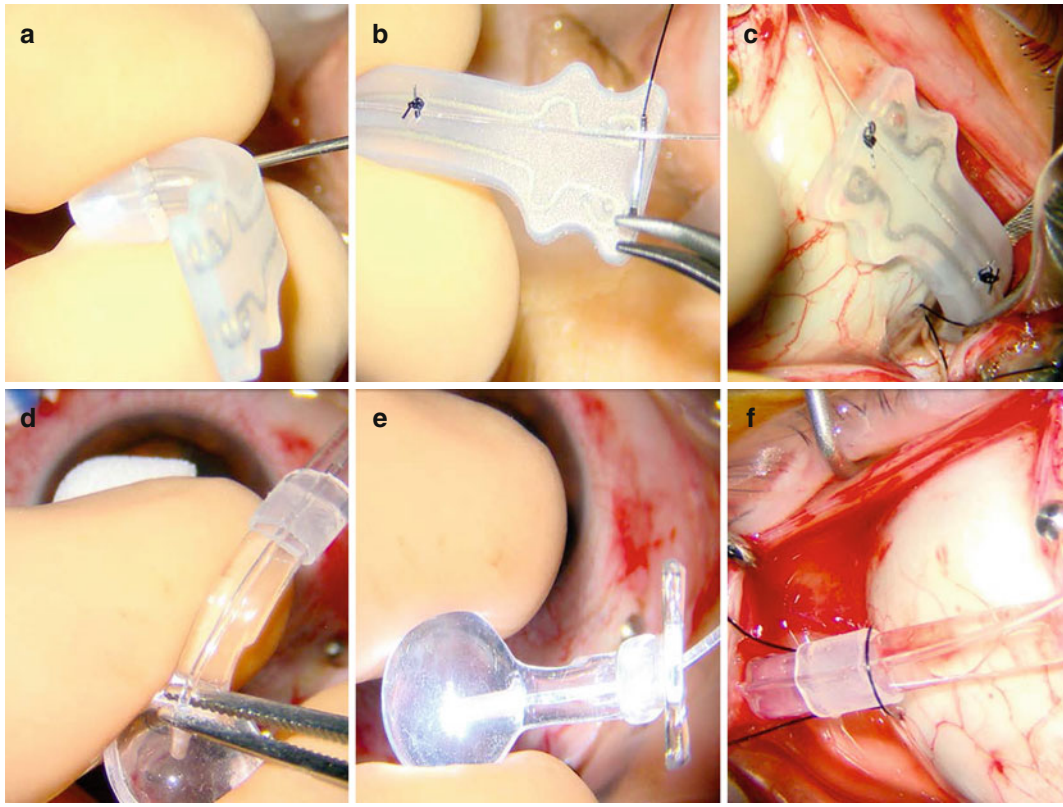

Fig. 1.13 Before placing the buckle, a 29G optic fiber can be inserted toward the center of the indenting platform as shown. (**a**) In case of Ando plombe it must be guided to the indenting head through a 23G needle shaft that (**b**) can be finally removed allowing the optic fiber to be fixed to the plombe with two 5/0 nylon sutures. (**d**, **e**) The AJL macular buckles have a groove in the indenting platform and an elastic strip to insert an optical fiber without the need of any sutures. (**c**, **f**) Finally, both macular buckles can be positioned under the mattress suture that has been inserted earlier

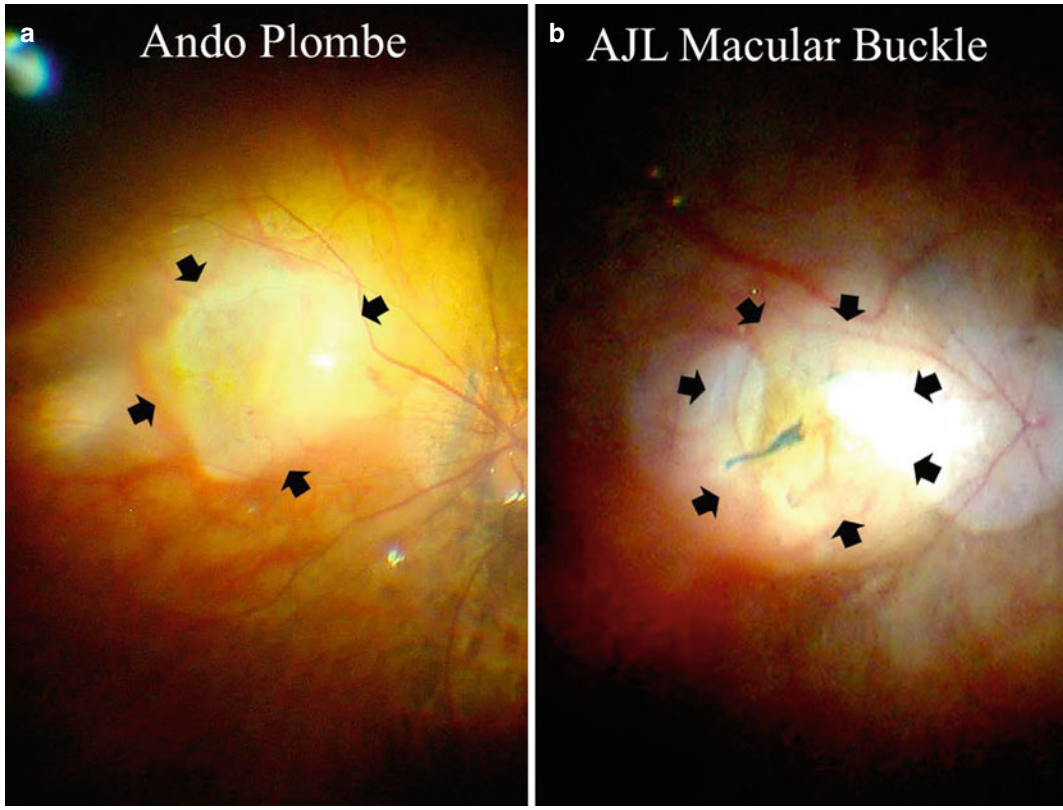

Fig. 1.14 The use of illuminated buckles offers the advantage of better and easier placement directly under the macular region via transillumination. Photo (**a**) shows an illuminated flat indenting platform of the Ando plombe. Photo (**b**) shows a transillumination produced by an illuminated, rounded, 10-mm indented platform of the AJL macular buckle. Moreover, a piece of ILM stained with brilliant blue which was left to mark the center of the macula can be easily observed

Finally, a PFC/air exchange and subsequent injection of non-expansible concentration of gas or silicone oil can be used as temporary intraocular tamponade. During the early postoperative period, patients are instructed to maintain a prone position for 5 days in the postoperative period.

1.3 Management of Surgical Complications

1.3.1 Suture of the Buckle to the Sclera

The scleromalacia that is characteristic of highly myopic patients makes the positioning of the scleral suture difficult because of the danger of perforation. It is therefore recommended to locate the thicker scleral zone and to place the buckle there. On some occasions perforation can occur and can cause a localized choroidal hemorrhage or subretinal hemorrhage (Fig. 1.16). In the case of either of these two complications, it is not necessary to drain them if they do not affect the central macular area.

1.3.2 Implant Extrusion

In some cases, the implant can be extruded when there is an uneventful rupture of the scleral sutures in the area of the scleromalacia or due to the opening of the conjunctiva (Fig. 1.17). In these cases it can be useful to coat the explant with pericardial patch graft or dura mater graft.

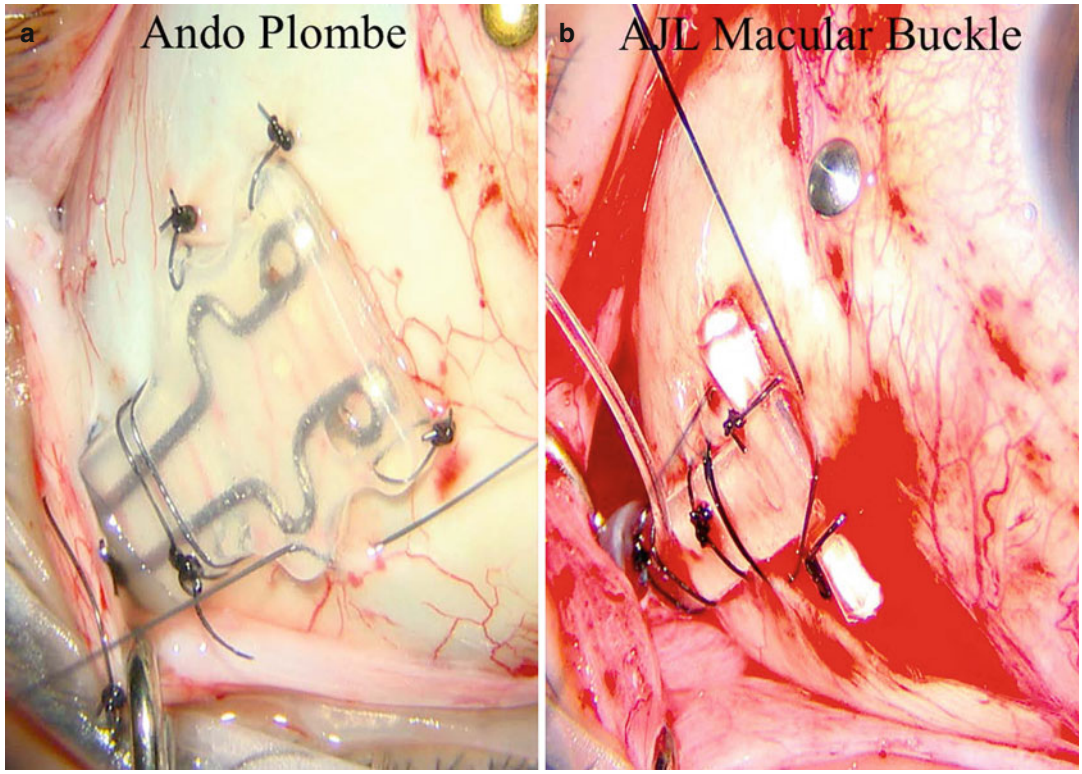

Fig. 1.15 (**a**, **b**) Once the buckle is in the desired position, the proximal end is fixated with an additional 5/0 nylon scleral sutures and the optic fiber is finally removed

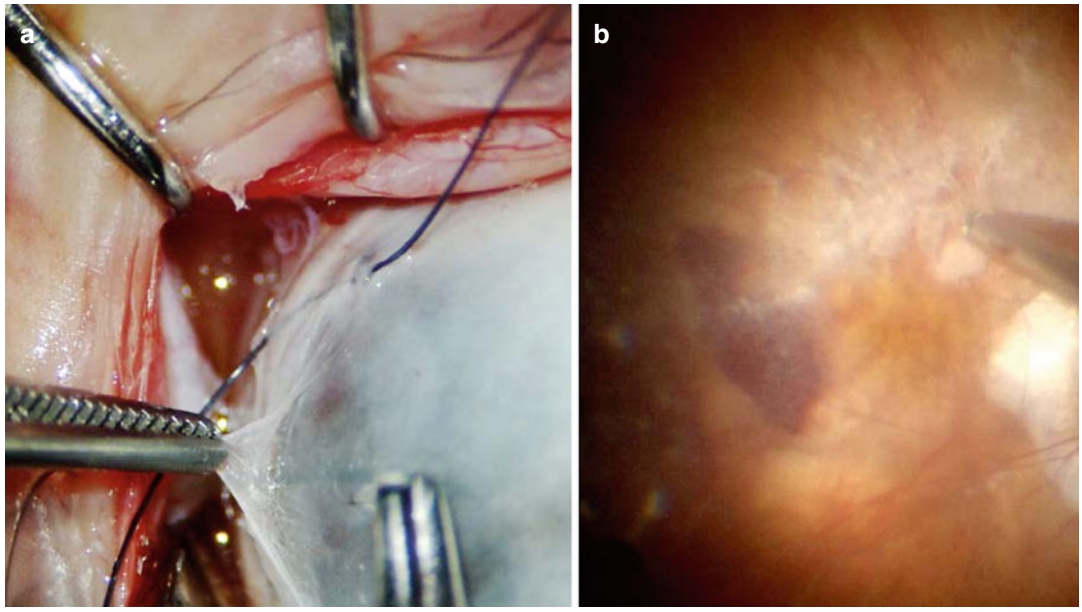

Fig. 1.16 (**a**) Severe scleromalacia can make it difficult to put the nylon 5/0 monofilament in place. (**b**) Subretinal hemorrhage temporal to the macula caused by a perforation of the scleral suture

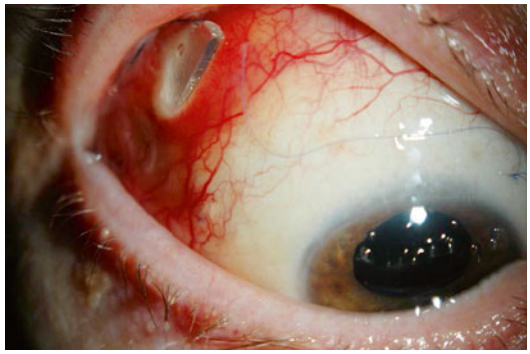

Fig. 1.17 Extrusion of the anterior part of the AJL macular buckle due to failure in the conjunctival suture. Corneal filaments are seen in the superior part of the cornea

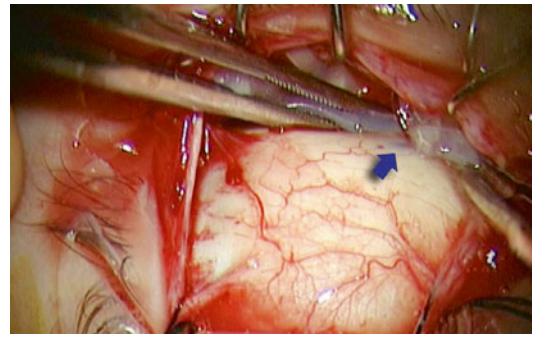

Fig. 1.18 Macular buckling procedure with a silicon band of 6 mm width, passing behind the inferotemporal vortex vein (*blue arrow*), where it can produce compression problems that could predispose it to choroidal detachment

Fortunately the total extrusion of the buckle is very uncommon, and in the cases where it has happened, in our experience, they have not been anatomical changes to the previous reattachment outcome.

1.3.3 Choroidal Hemorrhage

The high myopic patients have more risk of developing choroidal hemorrhage due to their low scleral rigidity. The manipulation of the sclera and the emplacement of posterior sutures could cause this complication. With the macular buckles that are to be positioned in one quadrant such as Ando plombe or AJL macular buckle, we should be cautious with the superotemporal vortex vein which is located in the insertion of the tendon of the superior oblique muscle. Because these buckles have to be positioned in the center of the superotemporal quadrant, it is less likely to injure this vein. However, there are other techniques, no less effective but more complex to pursue, such as the implantation of a silicone band of 6 mm of width, from the inferonasal quadrant to superotemporal quadrant, that pass underneath the macular area. Using this type of macular buckling, it is very important to place the silicone band behind the insertion of the tendon of the inferior oblique muscle and position it behind the place where the inferior temporal vortex veins perforate the sclera [31]. This maneuver needs special attention because it can compress the exit of this vortex vein and originate a choroidal detachment especially in the inferior quadrants (Fig. 1.18).

1.3.4 RPE Mottling/Disturbance/Changes

Even though not previously reported, we have observed postoperative RPE changes after using the Ando plombe buckle. We have noticed the appearance of alterations of the retinal pigment epithelium that can or cannot affect the center of the macular area and subsequently affected the functional outcome [31, 32]. Although the choroidal circulation studies have not demonstrated further conclusions to this eventuality, it is possible that compressive circumstances over the choroid could explain this complication (Fig. 1.19).

1.3.5 "Central Serous Chorioretinopathy-Like Appearance"

In addition to idiopathic central serous chorioretinopathy (CSC), macular serous detachment has been described in patients with tilted disk syndrome when the border of the staphyloma crosses the foveal area creating RPE distur-

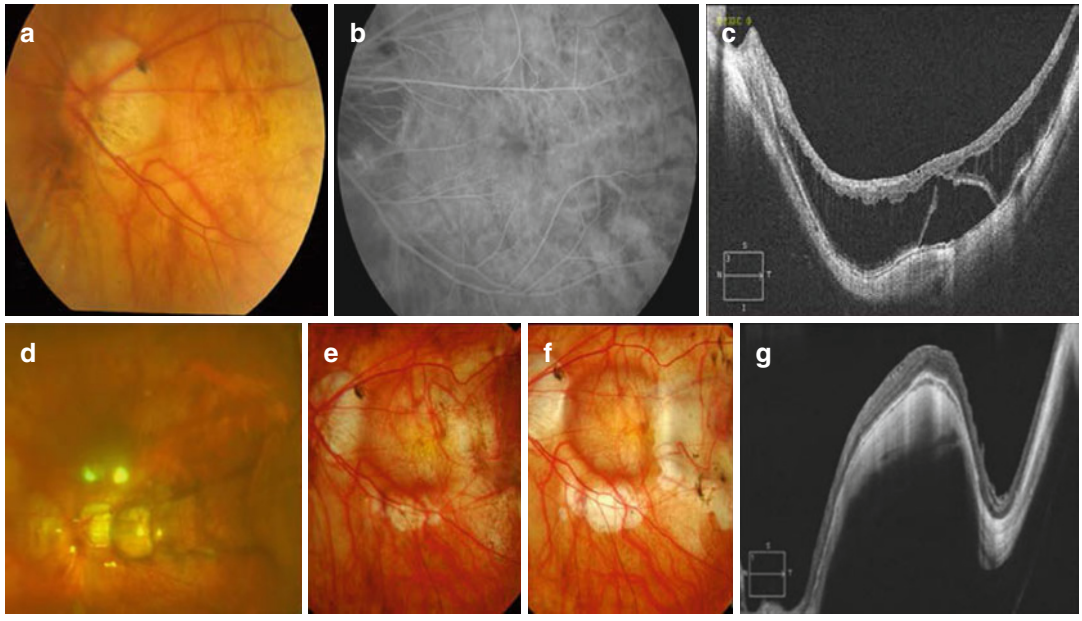

Fig. 1.19 (**a**) Preoperative retinography of a patient with retinoschisis and foveal detachment with BCVA: 20/63. (**b**) Fluoresce in angiography shows no RPE disturbance in the macular area. (**c**) OCT demonstrates both retinoschisis and foveal detachment. (**d**) First day after the surgery, Ando plombe buckling effect is easily seen. (**e**, **f**) Progressive RPE disturbance around the borders of the indenting tip, not affecting the foveal area. (**g**) OCT after 4 years of the surgical procedure shows the absence of schisis or foveal detachment and BCVA: 20/32. (Ultrawide-field color fundus photographs obtained with Optomap 200MA (Optos PLC, Dunfermline, Fife, Scotland); OCT scans obtained with Cirrus HD-OCT 4000 (Carl Zeiss Meditec, Dublic, CA); IMO (Instituto de Microcirugia Ocular), Barcelona, Spain)

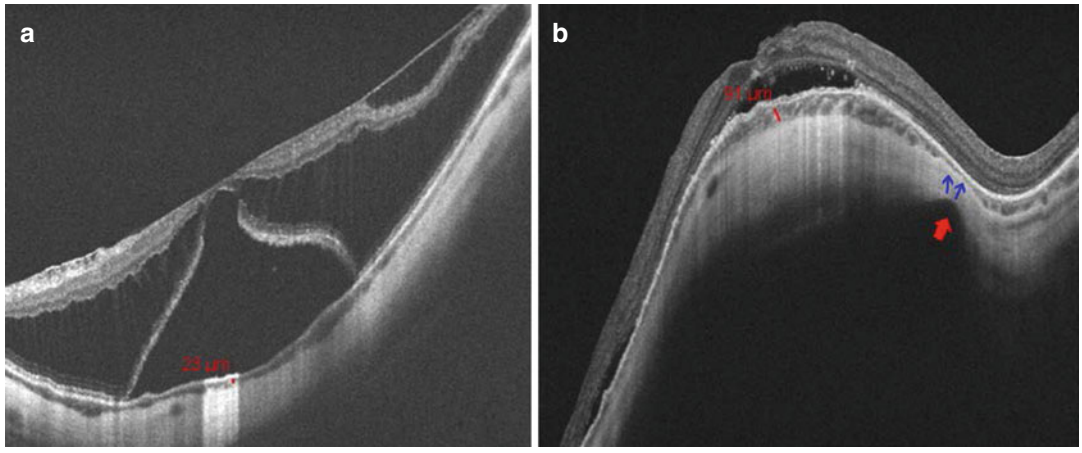

Fig. 1.20 (**a**) OCT shows schisis and a foveal detachment. Preoperative choroidal thickness is around 23 μm. (**b**) Six months postoperative OCT shows absence of the schisis but a residual foveal detachment is still present ("Central Serous Chorioretinopathy-like appearance"). The choroidal thickness in the subfoveal area was increased (91 μm), exactly as it has been described by OCT in case of idiopathic CSC. The *red arrow* shows the indenting border with squared angle of the Ando plombe. *Blue arrows* show the clear reduction of the choroidal thickness in this area. (OCT scans obtained with Cirrus HD-OCT 4000 (Carl Zeiss Meditec, Dublic, CA); IMO (Instituto de Microcirugia Ocular), Barcelona, Spain)

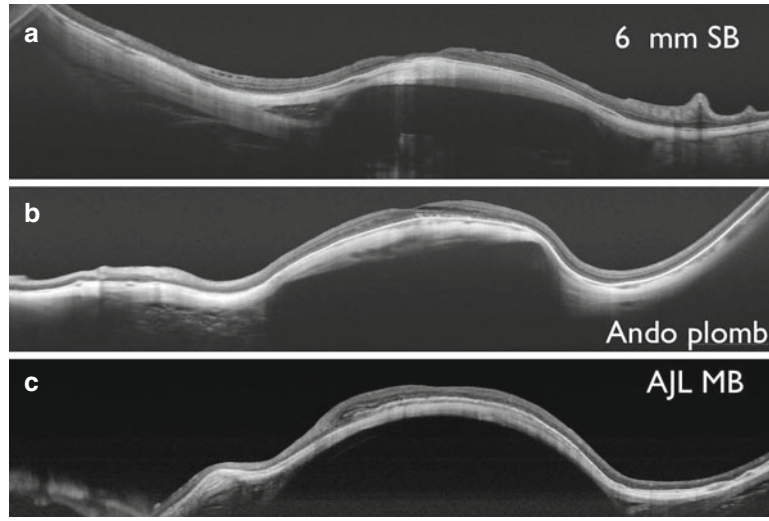

Fig. 1.21 SD-OCT with 12-mm line scans showing the different indenting profiles of three different indenting macular buckles. (**a**) Six-millimeter silicone band, running from inferonasal to superonasal quadrants, crossing the macular area. (**b**) Ando plombe with the squared angle borders of its indenting platform. (**c**) AJL macular buckle profile with rounded indenting platform. (OCT scans obtained with Atlantis Swept Source OCT-1 DRI (Topcom Corporation, Tokyo, Japan); IMO (Instituto de Microcirugia Ocular), Barcelona, Spain)

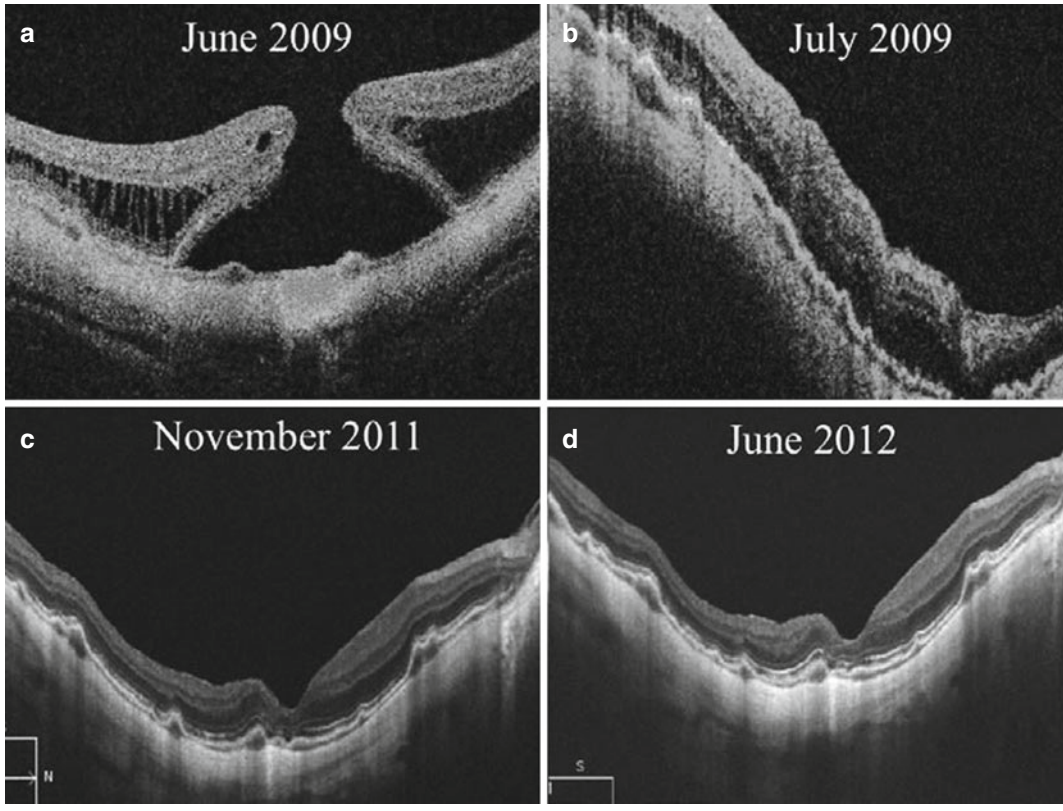

Fig. 1.22 (**a**) Preoperative OCT scan of a patient with macular hole (*MH*) and associated foveoschisis. (**b**) One month after MB procedure, OCT showed a slightly residual retinoschisis and a close MH. A degree of retinal "redundancy" can also be observed above the macular indentation. (**c**) A few months after surgery, the macular buckle was removed due to extrusion. However, more than 2 years after surgery, the MH was still closed and retinoschisis has not reappeared. (**d**) After 3 years of follow-up, the OCT scan reconfirmed the same previous status of the macula (OCT scans obtained with Cirrus HD-OCT 4000 (Carl Zeiss Meditec, Dublic, CA); IMO (Instituto de Microcirugia Ocular), Barcelona, Spain)

bance [41, 42]. In these cases an abnormal choroidal thickness is often seen. Macular buckling, especially the Ando plombe, can mimic this entity. An increase in choroidal thickness and retinal elevation have been observed in some cases, probably related to choroidal stasis produced by the compression of the choroid in the border of the indentation that changes to a right angle shape after surgery (Fig. 1.20). In our experience when this occurs, the removal of the macular buckle can make the subretinal fluid disappear. When we have used other types of macular buckling, we have not seen these types of alterations of the RPE or the thickening of the choroid either. This is probably because they do not have an acute border in the indentation platform (Fig. 1.21).

Conclusions

There is a common belief that MB technique needs a longer learning curve than PPV and it is surgically challenging. The technical difficulties and the risk of damaging the surrounding ocular structures seemed to restrict this procedure from becoming widespread. In contrast with other macular buckling techniques [25], our method does not imply a dissection or cutting of any rectus muscles. Furthermore, our method does not require placing the posterior sutures as close as possible to the optic nerve with the associated increased risk of injuring ciliary vessels. Moreover, using an additional light probe into the indenting head of the buckle in order to obtain a correct macular indentation avoids the need of additional surgical procedures in case of malpositioning [23]. In case of extrusion, diplopia, or infection, however, the macular buckle can also be removed, if necessary, and this seems to not influence anatomical outcomes even several years after (Fig. 1.22).

In conclusion, considering that we do not observe serious intra- or postoperative complications, many of which have been reported in literature [23, 25], and since both anatomical and visual outcomes are promising [27, 31–33], we suggest simultaneous episcleral and transvitreal approaches as the first surgical procedure used in cases of myopic traction maculopathy related to posterior staphyloma.

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Management of Complicated Vitreoretinal Cases in Children

2

Eric Nudleman and Antonio Capone Jr.

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E. Nudleman, MD, PhD
Department of Ophthalmology,
Shiley Eye Center and Jacobs Retina Center,
University of California, San Diego,
CA, USA
e-mail: enudleman@ucsd.edu,
eric.nudleman@gmail.com

A. Capone, Jr., MD (✉)
Department of Ophthalmology, Oakland University
William Beaumont School of Medicine, Associated
Retinal Consultants, Royal Oak, MI, USA
e-mail: acaponejr@arcpc.net, acaponejr@yahoo.com

2.1 Introduction

Pediatric vitreoretinopathies pose unique challenges to the retinal surgeon because of the distinct anatomic and physiological differences from adult retinal diseases. The pars plana, through which the vitreoretinal instrumentation may be safely introduced, is not fully formed until approximately the age of 8 or 9 months, thereby necessitating entry through the pars plicata when a posterior approach is desired in the newborn eye [17]. The vitreous gel, which is well formed and firm in normal newborn eyes, may be optically empty or abnormally syneretic in various pediatric diseases. The vitreoretinal adhesion is stronger in children than in adults, making the surgical induction of posterior vitreous detachment relatively difficult [19, 44]. The biochemistry of the newborn eye is influx, with rising and falling levels of vascular endothelial growth factor (VEGF), insulin-like growth factor 1, tumor growth factor-b, and other cytokines, which may affect the progression or stabilization of pediatric vitreoretinopathies [10, 47, 54]. To operate safely, the pediatric vitreoretinal surgeon must understand the characteristics that define diseases, such as retinopathy

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of prematurity (ROP), familial exudative vitreoretinopathy (FEVR), persistent fetal vasculature syndrome (PFVS), congenital x-linked retinoschisis (CXLRS), and Coats disease. Here we discuss key features of the surgical approach to complicated pediatric vitreoretinopathies.

2.2 Retinal Detachment in Retinopathy of Prematurity

The international classification of ROP is well established [22]. A stage 4A detachment is subtotal and spares the macula, whereas a stage 4B detachment is subtotal and involves the macula. A stage 5 detachment is a total retinal detachment. In the Early Treatment for Retinopathy of Prematurity (ETROP) study, 9.1 % of eyes progressed to retinal detachment following laser photocoagulation at 2 years [14]. ROP retinal detachments may have varying degrees of hyaloidal organization and preretinal proliferation, but most lie on a spectrum from primarily exudative to primarily tractional in etiology.

The international classification system of ROP was designed to characterize untreated eyes. Once peripheral laser ablation has been performed, anatomic permutations may defy simple categorization. After peripheral laser scars have formed, a true stage 5 retinal detachment cannot occur because the far peripheral retina remains attached. However, the retina may appear totally detached on clinical examination if the space between the attached peripheral retina and the more central proliferative tissue is not readily visible. We describe such retinal detachments as "stage 4b/5" because they are technically stage 4b detachments but are clinically indistinguishable from stage 5 detachments without the knowledge of earlier laser treatment.

Predominantly exudative retinal detachments are believed to occur as a consequence of vascular leakage into the subretinal space [19]. Exudative detachments in ROP have been reported following both cryotherapy [53] and laser photocoagulation [34–36]. The appearance of a predominantly exudative detachment differs from a predominantly tractional detachment due to the presence of copious subretinal lipid and the absence of preretinal cicatricial fibers (Fig. 2.1). Effusive detachments can be safely managed medically with aggressive steroid therapy and cycloplegia.

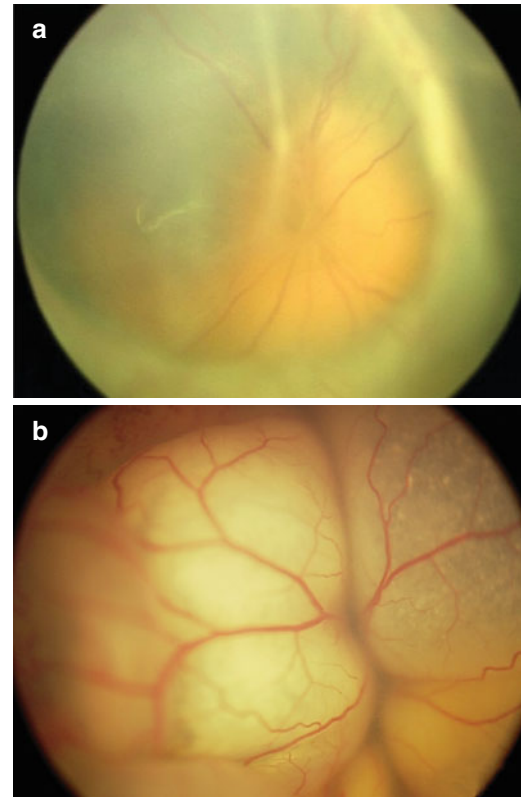

Fig. 2.1 Tractional versus exudative retinal detachment in advanced ROP. (**a**) RetCam photogram of stage V tractional retinal detachment with open funnel configuration, demonstrating anterior fibrous ring. (**b**) Exudative retinal detachment demonstrating smooth contour with subretinal lipid and absence of cicatricial fibers

Predominantly tractional retinal detachments in ROP occur due to formation of fibrous proliferation along the ridge tissue and extending into the overlying vitreous. The vitreous sheets act as scaffolds for the extension of the fibrotic tissue. Contraction occurs along various vectors, most commonly toward the center of the eye, as well as posterior toward the optic nerve or anterior toward the lens. The tractional vectors can be summarized as (1) intrinsic to the retina, (2) ridge to lens, (3) ridge to ridge, (4) ridge to ciliary body, (5) ridge to retina, and (6) persistent stalk tissue (Fig. 2.2).

Knowledge of the tractional vectors present in ROP is critical to surgical success. The primary

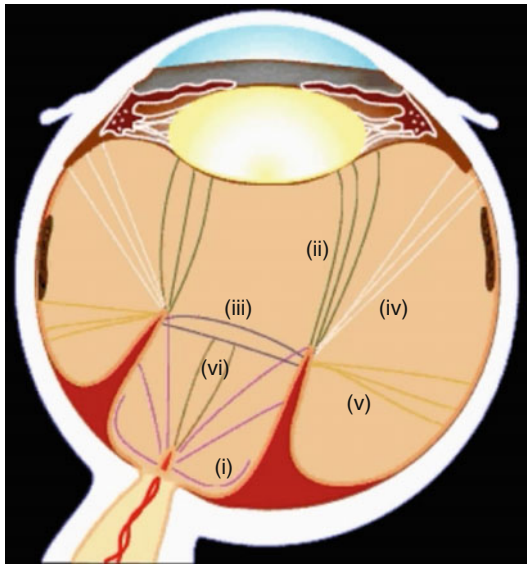

Fig. 2.2 Schematic demonstrating the tractional vectors in advanced retinopathy of prematurity, including (i) intrinsic to the retina, (ii) ridge to lens, (iii) ridge to ridge, (iv) ridge to ciliary body, (v) ridge to retina, and (vi) persistent stalk tissue

surgical goal in ROP detachments is interrupting the traction resulting from fibrous proliferation. Successful efforts can prevent the progression from stage 4A to stage 4B or from stage 4B to stage 5, reduce dragging of the macula, and spare visual function. Successful reattachment has been reported in 74–91 % of stage 4A detachments [4, 6, 21, 26, 34, 46], 62–92 % of stage 4B detachments [8, 21, 26, 41, 46, 58], and 22–48 % of stage 5 detachments [9, 15, 27, 49, 50]. In stage 5 detachments, partial residual retinal detachment is common, but the goal is to remove the traction so as to reattach as much of the retina as possible and provide a stable anatomic result. Visual outcomes in successful repair of stage 4A detachment can be expected to be 20/80 or better [21, 28, 39], ambulatory vision following stage 4B repair [41], and form vision following stage 5 repair [33, 51].

2.3 The Timing of Surgical Intervention in Retinopathy of Prematurity

ROP is characterized by a relatively predictable timeline of progression. Initial manifestations of the disease are usually seen approximately 32 weeks postmenstrual age (PMA), and the threshold for laser ablation is reached at a mean of 37 weeks PMA [37, 43]. Retinal detachment after appropriate laser ablation occurs at a mean of 41 weeks PMA [42]. The most dramatic exception to this timeline is aggressive posterior ROP that is characterized by rapid progression of zone 1 or posterior zone 2 plus disease and ill-defined retinal neovascularization to retinal detachment [22].

The rapidity of disease progression correlates to some degree with the level of retinal vascular activity at the time of retinal detachment. Surgery for stage 4A ROP targets interruption of transvitreal proliferative condensations. For this reason, vascular activity is rarely a reason to defer surgical intervention. In general, once surgical intervention is necessary for stage 4A ROP, the earlier the procedure is performed, the better to minimize the extent of the detachment.

Surgery for stages 4B and 5 ROP typically entails the mechanical removal of preretinal proliferation. An eye with a high degree of vascular activity, as represented by plus disease, florid retinal neovascularization, and rubeosis iridis, is likely to encounter significant intraoperative bleeding. In eyes with stage 4B or stage 5 detachments in the setting of significant vascularity, it is usually necessary to wait until 48–52 weeks PMA for vascular activity to decrease to intervene [18].

2.4 Lens-Sparing Vitrectomy

In most stage 4A and many stage 4B ROP detachments, it is possible to relieve traction with a lens-sparing vitrectomy (LSV). The eye is entered at the pars plicata, approximately 0.5 mm posterior to the limbus. A two-port approach using an infusing light pipe or pic and three-port approach using a separate infusion line have both been reported with similar success rates [6, 21, 26, 31]. A core vitrectomy is carefully performed with attention to the vectors of traction. Specifically, an effort should be made to address the transvitreal ridge to ridge tissue, ridge to periphery, ridge to lens, and optic nerve head to the ridge (Fig. 2.2). In many cases, successful release of

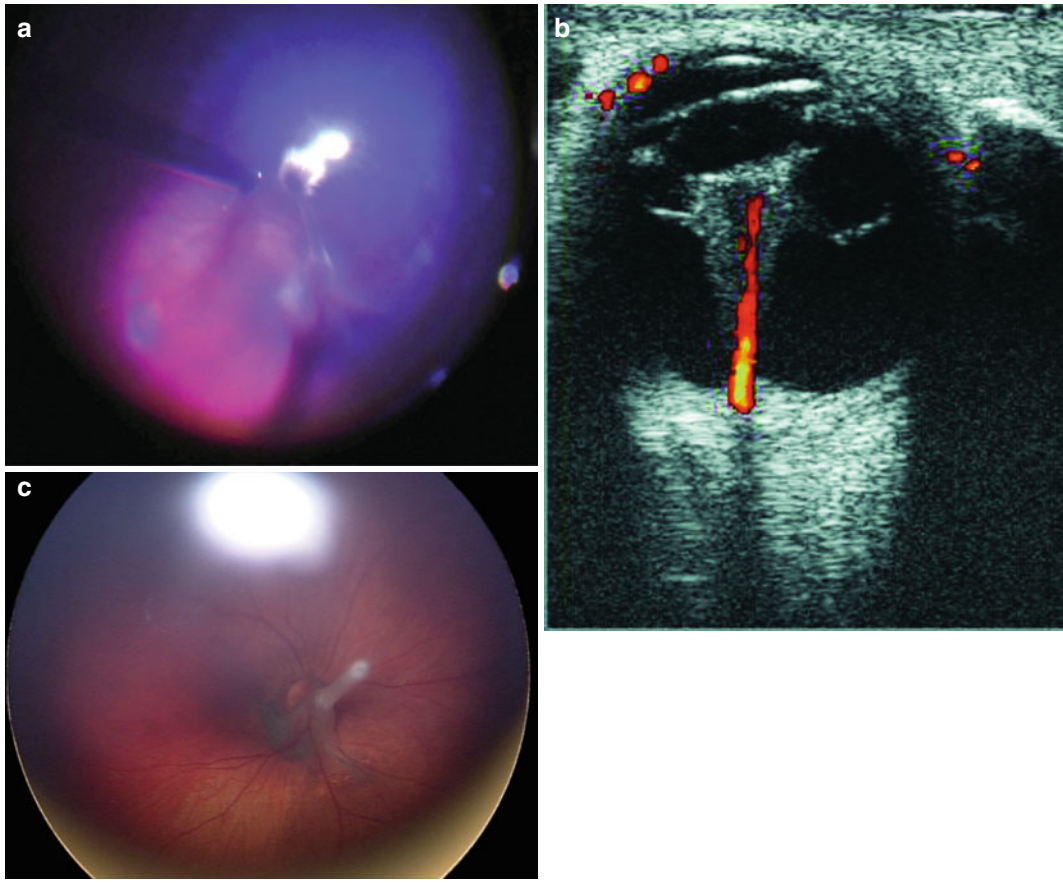

Fig. 2.3 Stalk tissue in persistent fetal vascular syndrome. (**a**) Intraoperative photograph demonstrating traction on the retinal tissue with dragging of retinal vessels into the stalk. (**b**) Doppler ultrasound showing vessels within the stalk approaching the posterior lens capsule. (**c**) One month postoperative photograph following transection of the anterior stalk with retraction of the stalk tissue

traction is evident during the case with relaxation of the tented retina. When the dissection is complete, a fluid-air exchange is performed, and the sclerotomies are sutured. Persistent subretinal fluid is expected at the conclusion of the case and will reabsorb over the course of weeks to months. Similarly, this approach is effective in treating the tractional component of stage 3B and stage 4B FEVR detachments [38].

In some cases of stage 4 ROP-related retinal detachments, anterior ridge to ciliary body tissue cannot be safely dissected by a transvitreal approach without damaging the crystalline lens. In such instances, the surgeon can cleave these anterior bands at the time of entry into the eye by placing the MVR blade through the sheet of tissue and drawing back, an approach described as an *ab interno* incision [20]. The tissue can be incised parallel to the lens capsule once the blade has entered into view; however, care must be taken to avoid the lens equator on entry. Safe entry is accomplished by pointing the instrument posteriorly, parallel to the visual axis. If the anterior bridging tissue between the retina and the lens-ciliary body diaphragm cannot be safely separated through the pars plicata incisions, then a lensectomy and an anterior approach may be necessary to safely relieve vitreoretinal traction and allow for retinal relaxation.

In some cases of PFVS, the stalk tissue is attached eccentric to the visual axis and extends posteriorly. Traction is exerted on the posterior

lens surface and on the posterior pole. To address this traction, a lens-sparing technique with entry similar to a stage 4 ROP-related detachment can be performed. In contrast to the approach to ROP-related retinal detachment, the first step is to divide the stalk anteriorly without vitrectomy [45]. This is accomplished with an MPC type scissor, with careful attention to avoid manipulating the stalk, which can result in damage to the posterior lens capsule. Once the stalk has been divided, the anterior remnant is not manipulated. This is to avoid damage to the intrinsic retinal vessels and folds of retinal tissue, which may be dragged into the stalk as far as two-thirds the distance toward the lens (Fig. 2.3). The posterior stalk often retracts several millimeters immediately following transection, demonstrating the effect of the traction (Fig. 2.3). A limited core vitrectomy is then performed and the sclerotomies are closed. This approach has been demonstrated to improve function with resolution of strabismus without muscle surgery in the majority of children with this presentation [45].

2.5 Limbal Approach for Lensectomy and Vitrectomy

In cases of advanced retinal detachment or a poor view posterior to the lens, including stage 5 ROP, stage 5 FEVR, and PFVS cases with diffuse retrolental plaques, the risk of creating an iatrogenic retinal break may outweigh the benefits of performing lens-sparing surgery, and an anterior (translimbal) approach to lensectomy and vitrectomy may be preferable. When an anterior approach is desired, an inferotemporal or inferior infusion cannula is placed at the limbus to stabilize the anterior chamber initially and the unicameral anterior-posterior chamber subsequently. Limbal incisions are then made superonasally and superotemporally. The pediatric crystalline lens is aspirated with a vitrector once the anterior lens capsule has been opened. Importantly, the goals of lensectomy in such a situation differ from those of the removal of an uncomplicated congenital cataract. The benefits of preserving capsular support for potential secondary intraocular lens implantation in the future are outweighed by the likelihood of residual capsule serving as a scaffold for preretinal proliferation and circumferential vitreoretinal contraction. Once the residual capsule and the ciliary body are drawn into a contractile anterior ring, the ensuing hypotony may be difficult to treat both because the anterior contractile ring is difficult to visualize and safely dissect and because the ciliary body sustains permanent injury. Even in cases of chronic total retinal detachment with lenticuloretinal apposition, capsular material can generally be stripped away from the retina without causing retinal breaks. The surgeon may then proceed with anterior dissection of preretinal proliferative tissue, hyaloidal organization, or anterior stalk tissue.

2.6 Minimal Intervention to Achieve Surgical Goals

As in adult vitreoretinal surgery, the goals of pediatric vitreoretinal surgery are generally evident at the outset of the procedure: removal of significant media opacities, relieving of the transvitreal or vitreoretinal traction, peeling, and removal of the proliferative tissue. However, the risks of operating in an aggressive manner are far greater in children than in adults. Simply put, perfection is expensive in terms of risk of complications. In particular, the consequences of creating an iatrogenic retinal break can be devastating in children because of the massive proliferative response that often ensues [19]. As the pediatric vitreous is relatively well formed and is adherent to the retinal surface, the surgeon may be tempted to shave close to the retina with the vitreous cutter to remove the preretinal vitreous cortex. Such a maneuver is useful only rarely in pediatric cases and should be avoided in the absence of very specific relevant surgical goals. Performing a vitrectomy without complete removal of the posterior hyaloid in a child may lead to posterior hyaloidal contraction syndrome and retinal detachment, but in our experience this rare sequela does not warrant aggressive removal of adherent vitreous cortex on a routine basis [23].

2.7 Enzymatic Targeting of the Vitreoretinal Junction

The vitreoretinal adhesion is mediated in part by laminin and fibronectin [25]. Plasmin enzyme, either the intact protein procured from blood obtained from the patient (autologous) or a parent (heterologous) or the recombinant fragment ocriplasmin (Jetrea), can be administered to cleave laminin and fibronectin and facilitate posterior vitreous detachment [12, 30]. In adult cases with unusually strong vitreoretinal adhesions, such as in proliferative diabetic retinopathy, plasmin facilitates the surgical induction of posterior vitreous detachment [3, 52]. Ocriplasmin has also been evaluated for the treatment of vitreomacular adhesion in two randomized controlled studies and was shown to induce a posterior vitreous detachment in 30 % of patients [48].

A subset of pediatric vitreoretinal surgery requires successful peeling of preretinal membranes or the posterior hyaloid to achieve primary surgical goals, and plasmin may be useful in these situations. The posterior hyaloidal contraction syndrome is perhaps the most direct example, as a persistent vitreoretinal adhesion combined with hyaloidal contraction is relieved by successful vitreoretinal separation [23]. Preretinal proliferative membranes are also central components to the pathology of advanced cases of ROP, FEVR, CXLRS, and PVR-associated retinal detachments. The use of plasmin enzyme or ocriplasmin may facilitate the removal of such membranes and reduce the risk of creating an iatrogenic retinal break during membrane peeling (for review, see [55]). In young children who cannot tolerate an intravitreal injection in the clinic, plasmin is injected into the vitreous cavity following induction of general anesthesia, and surgery initiated approximately 30 min thereafter.

2.8 Retinal Folds Versus Stalks

Stalk tissue extending from the disk toward the posterior aspect of the crystalline lens is characteristic of PFVS [16]. The stalk tissue represents residual hyaloidal vasculature, which may include elements within the vitreous cavity, as well as remnants of the tunica vasculosa lentis, which surrounds the lens. The hyaloid system normally begins to regress by 12 weeks' gestation and is completely regressed by 35–36 weeks' gestation [59]. The main hyaloid trunk is the last element to undergo regression. As a result, persistent fetal vasculature is often present in pediatric vitreoretinopathies where the normal development program failed, and the surgeon must differentiate persistent stalk tissue from a retinal fold to identify and address the pathology.

The stalk tissue may be fibrous or contain patent vessels. In ROP, the stalk tissue can be adherent to the detached retina, complicating the surgical dissection [11]. FEVR is a disease characterized by radial retinal folds, which may be pulled anteriorly by transvitreal traction toward the lens-ciliary body diaphragm. Persistent fetal vasculature may be found along the edge of the fold, and the fold itself may be difficult to identify clinically when viewed on end (Fig. 2.4). In such a case, if a

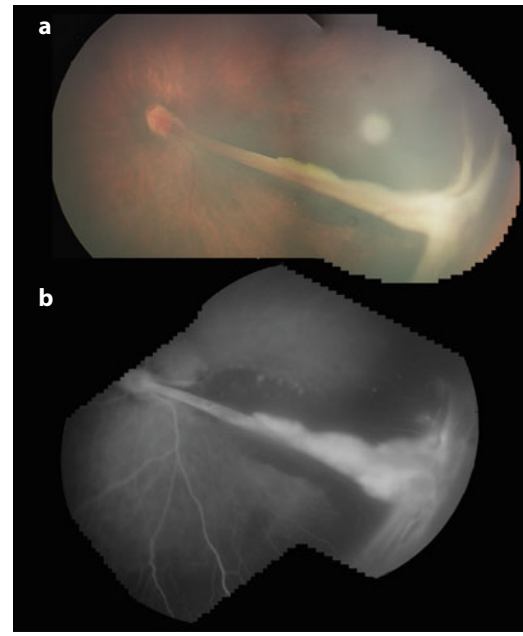

Fig. 2.4 Radial retinal fold in FEVR. (**a**) Montage color photograph of the left eye demonstrating knifelike radial fold extending through the macula to the anterior periphery and posterior lens capsule. (**b**) Montage fluorescein angiogram of same eye demonstrating retinal vessels draw into fold with vasculature extending to the far periphery

knifelike fold is mistakenly identified as a stalk, the diagnosis of FEVR may be missed entirely [40]. A limited clinical examination in an uncooperative child may limit the physician's ability to distinguish between a fold and a stalk, and examination under anesthesia may be necessary.

2.9 Fluorescein Angiography for the Detection of Subclinical Avascularity

Primary avascularity of the peripheral retina is a key feature of several pediatric vitreoretinopathies [5, 22]. In ROP, the staging system depends on the ability of the clinician to identify the line (stage 1) or ridge (stage 2) separating vascular and avascular retina and any neovascularization that may extend from the ridge (stage 3). VEGF is produced by the avascular peripheral retina, thereby fostering retinal neovascularization and intraretinal vascular changes [57]. Peripheral avascularity is also seen in FEVR, Coats disease, CXLRS, and incontinentia pigmenti, although the relationship between disease activity and VEGF produced by an avascular peripheral retina is less clear in these conditions. Areas of avascularity may escape detection on clinical examination when they are not bounded clearly by a demarcation line or a ridge. FEVR, in particular, is characterized by crescents of peripheral retinal nonperfusion, which may be difficult to identify without angiography [24]. In Coats disease, patches of nonperfused retina may be seen anteriorly or adjacent to characteristic vascular changes. In CXLRS, retinal nonperfusion may occasionally be seen within areas of retinoschisis. The standard of care for the treatment of ROP does not require fluorescein angiography, but angiography may be appropriate when an inadequate clinical response is seen after standard-of-care peripheral laser ablation, as angiography may identify islands of retinal nonperfusion posterior to the clinically identifiable ridge, which usually demarcates vascular and avascular retina. Fluorescein angiography is also invaluable in the detection of posterior avascular islands in FEVR, Coats disease, and incontinentia pigmenti (Fig. 2.5). The treating surgeon may then apply ablative laser to the avascular retina, although the efficacy of such treatment remains to be confirmed in a large case series or in a prospective study [56]. Broad areas of clinically inapparent avascular retina may also be present in conditions

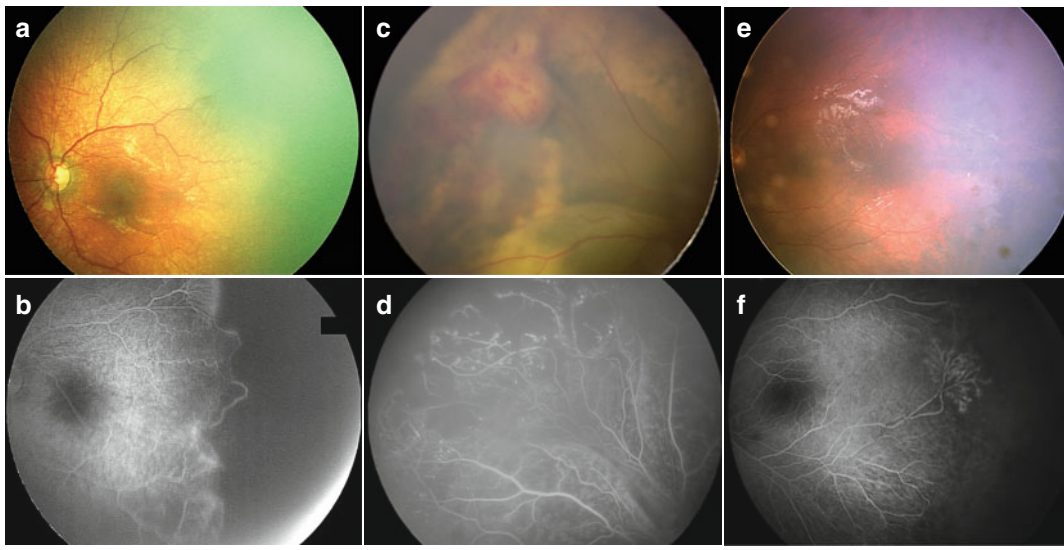

Fig. 2.5 Fluorescein angiography of peripheral retina. (**a**) RetCam color photograph and (**b**) FA of patient with incontinentia pigmenti demonstrating peripheral avascularity. (**c**, **d**) Peripheral avascular islands in Coats disease. (**e**, **f**) FEVR with peripheral avascularity and frond of neovascularization at the vascularized border

not usually thought to be associated with retinal nonperfusion. Shaken baby syndrome is characterized clinically by intraretinal hemorrhages extending to the ora serrata and occasionally preretinal or subhyaloid hemorrhages [1, 32]. Retinal nonperfusion is often apparent on fluorescein angiography [13]. The implications and management of such nonperfusion are unclear, but these findings likely warrant close follow-up for signs of neovascular sequelae secondary to ischemia.

2.10 Complications of Syndromic Myopia in Infants and Children

The syndromic conditions associated with myopia in infants and children, such as Stickler and Marfan syndrome, have unique vitreoretinal features predisposing them to retinal tears and detachments. These children often present with chronic macula-off retinal detachments associated with PVR. Although such eyes may be repaired successfully employing contemporary vitreoretinal surgical techniques, they frequently require multiple surgical procedures, and visual results can be disappointing due to amblyopia. The high emotional and financial cost, in addition to the high rate of bilaterality of retinal detachment, justifies consideration of prophylactic retinopexy of the fellow eye in these patients. Both cryotherapy and laser photocoagulation applied contiguously 360° and posterior to the vitreous base have reduced rates of detachments in the fellow eyes of patients with Stickler syndrome [2, 7, 29]. Peripheral retinopexy for such eyes is not a panacea: failure ranges from approximately 6 to 10 %. With the advanced presenting pathology of many of these patients, prophylactic retinopexy of the fellow eye may be the most important procedure performed.

Conclusions

Surgical management of pediatric vitreoretinopathies can be complex. Successful intervention in these diseases requires an understanding of the relevant anatomy and biochemistry. Examination under anesthesia with careful attention to detail and fluorescein angiography or ultrasonography when appropriate can provide the pediatric vitreoretinal surgeon with crucial information before surgery. Overly aggressive surgical techniques, failure to recognize anterior or posterior retinal folds, or inadvertent intraoperative traction on vitreoretinal adhesions may result in iatrogenic retinal breaks with catastrophic consequences. A careful and conservative surgical approach is therefore particularly important when performing surgery in eyes with pediatric vitreoretinopathies.

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Vitrectomy for Complicated Posterior Uveitis

3

Lisa J. Faia and George A. Williams

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3.1 Introduction

Uveitis remains a devastating and sight-threatening group of diseases. Worldwide, uveitis is thought to be responsible for 10 % of cases of all blindness [1]. The field of uveitis is one that has changed significantly over time and continues to evolve. Surgical management of complicated posterior uveitis requires good preoperative planning as well as good surgical sense [2–10].

Posterior uveitis encompasses a number of diseases and possible complications. Complications which require surgical management include epiretinal membranes, cystoid macular edema resistant to immunosuppressant therapies, rhegmatogenous retinal detachments (RRD), and tractional retinal detachments (TRD) [11–15]. Retinal detachments that occur in the presence of ocular inflammation can be especially challenging and present with a guarded visual prognosis. They can be related to infectious as well as inflammatory causes. Tractional retinal detachments as well as combined detachments can also be seen in both infectious as well as inflammatory ocular settings. It is important to establish the underlying etiology and to, the best of the surgeon's ability, have the inflammation controlled prior to surgery. Surgery in the management of complicated posterior uveitis can be diagnostic and/or therapeutic, depending on the indications [16].

L.J. Faia, MD (✉) • G.A. Williams
Department of Ophthalmology,
William Beaumont Hospital,
Royal Oak, MI, USA
e-mail: faia.lisa@gmail.com, lfaia@arcpc.net;
gwilliams@beaumont.edu

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3.2 Preoperative Evaluation

Though there are times when a vitreoretinal surgeon must operate on an inflamed eye, such as with infectious endophthalmitis, for the most part it is most advantageous for a proper preoperative evaluation to be performed and the inflammation controlled [17]. Results of surgery performed during times of active inflammation generally have poorer results [18]. Besides assessing the nature of the uveitis complication, the etiology of inflammation should be assessed and proper systemic therapies instituted before surgery.

Besides ordering clinically relevant laboratory testing, preoperative ancillary assessment may include fluorescein angiography (FA), indocyanine green angiography (ICG), optical coherence tomography (OCT), B-scan ultrasonography, and electroretinography (ERG). Fluorescein angiography may disclose retinal ischemia and/or leakage of the optic nerve or vessels, serving as a surrogate marker for inflammatory activity. Indocyanine green angiography can also be helpful to reveal choroidal abnormalities not detected on clinical examination or FA. Optical coherence tomography is helpful in confirming the presence of epiretinal membranes and in distinguishing inflammatory macular edema from that due to vitreomacular traction. In the presence of media opacity or hypotony, B-scans may be helpful in detecting hidden posterior pathology which may influence the surgical plan. Electroretinography may be useful in detecting less than readily apparent inflammatory activity.

3.2.1 Timing

In uveitis, the dictum is to operate on a quiet eye whenever possible. Beginning with a pars plana vitrectomy before systemic therapy for inflammatory control may be more detrimental, and preoperative immunomodulatory therapy should be initiated [19, 20]. While complete inflammatory quiescence may not be attainable or realistic in some patients requiring urgent care, the experience from surgeons operating on uveitic eyes for other reasons suggests that vigorous efforts to establish a definitive diagnosis and aggressive control of perioperative inflammation are essential both for successful surgical outcomes and to reduce the risk of postoperative complications [21–23]. For non-emergent procedures, quiescence should be maintained for a minimum of 3 months prior to surgery. Based on the type of uveitis, pre-, peri-, and postoperative increases in systemic immunosuppression are often required, especially in more severe cases.

For eyes with posterior uveitis, even if quiet, there is a risk of reactivation. One suggested strategy is to increase the patient's systemic steroid-sparing immunosuppression before surgery. Since most medications require 4–6 weeks for full activation, this is not always the best option. Depending on the severity, oral steroids (up to 1 mg/kg) should be started 3–5 days prior to surgery with a slow taper after surgery. For more severe cases, IV Solu-Medrol (1 g IV) should be given the day before surgery, day of surgery, and day after, followed by a slow taper with oral prednisone. This aggressive corticosteroid therapy may also apply with cases in which one must operate on an inflamed eye. In infectious causes, such as acute retinal necrosis, toxoplasmosis, and toxocariasis, it is important that systemic therapies are on board as soon as possible.

3.3 Reasons for Surgery

3.3.1 Diagnostic

Many tools are used in the diagnosis and treatment of these diseases and their complications. Vitrectomy can be used in both a diagnostic and therapeutic fashion. Uveitis involving the posterior segment can have a number of etiologies to consider. When the diagnosis is in question, a vitrectomy can be helpful in revealing an inflammatory versus an infectious versus a neoplastic source. Cultures can be obtained for possible bacterial, fungal, or mycobacterial source. PCR has been very helpful for viral sources, toxoplasmosis, toxocariasis, tuberculosis, and syphilis. It is also helpful for obtaining the Goldmann-Witmer quotient. Cytology and flow cytometry, even with such small samples, can be helpful for

diagnosis [24]. Case series of diagnostic vitrectomies reported yields from 30 to 81.6 % [25]. Yield is improved in the presence of good clinical judgment and with the use of the latest laboratory techniques.

3.3.1.1 Technique for Vitreous Sampling

This technique can be performed under peribulbar or general anesthesia. A standard three-port vitrectomy can be used. The infusion is kept off until the sample is withdrawn. The infusion cannula may help to maintain the intraocular pressure following biopsy, preventing sudden hypotony by intermittently turning on the infusion or using air to prevent the eye from collapsing. Approximately 1 ml of vitreous is obtained directly from the vitrectomy hand piece (20-, 23-, or 25-gauge cutter) through an inline stopcock and tubing attached to a syringe, which is held by the assistant providing passive suction [26, 27]. Apart from allowing the visualization of the fundus and allowing better diffusion of intraocular medications, the vitrectomy also has the advantage of yielding more samples with enough material available for multiple tests. Studies have also shown a better yield from samples which have been obtained closer to the retina, theorizing that these cells may be more viable compared to the more distal cells [24].

3.3.2 Therapeutic

The most common reason for surgical intervention in posterior uveitis is for visual rehabilitation. Indications for therapeutic vitrectomy include (1) significant media opacity causing visual loss or precluding adequate view of the posterior segment, (2) endophthalmitis or lens-induced uveitis, and/or (3) repair of structural complications of uveitis.

3.3.2.1 Retinal Detachment

Though uveitis itself has not been considered a significant predisposition for RD, a retrospective review found an RRD rate of 3.1 % among uveitis patients [28]. The rate is significantly higher in infectious forms of uveitis, such as acute retina necrosis (50 %), progressive outer retinal necrosis (70 %), and those with cytomegalovirus retinitis due to HIV (2.3/100 eye-years) [29–31]. Other forms of infectious uveitis, such as those from parasitic infections [(i.e., toxoplasmosis) and helminthic (i.e., toxocariasis)], can also lead to RD formation. Rates of RD formation with toxoplasmic retinochoroiditis run from 3.5 to 6 %, though Adan et al. found a rate of 53.3 % in these patients, both with pure RRD and combined RRD/TRD [32–35]. In ocular toxocariasis, tractional detachments of the macula can occur in 30 % of patients and TRDs in 40 % of cases with peripheral lesions with traction (Fig. 3.1) [28, 36].

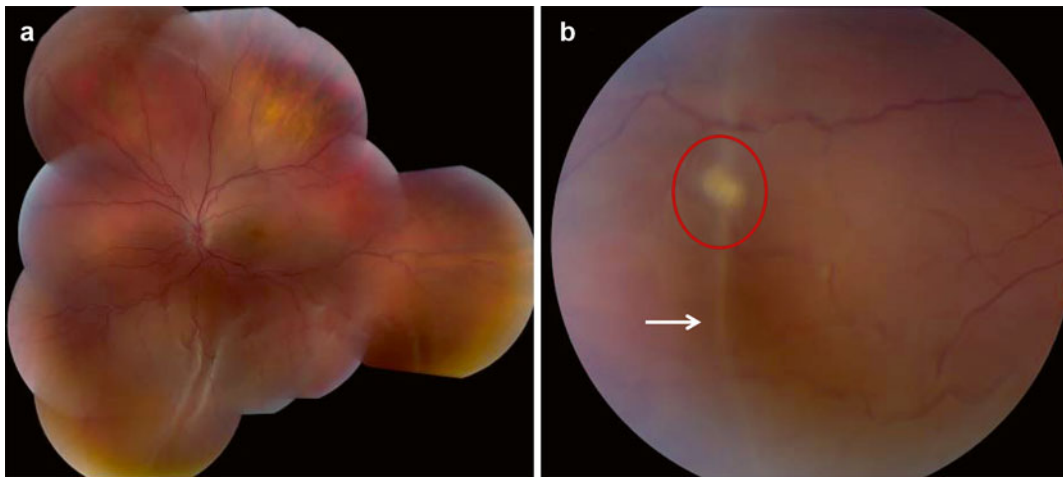

Fig. 3.1 (**a**) Fundus photograph of an 18-year-old male with a macula involving combined rhegmatogenous and tractional retinal detachment from toxocariasis. (**b**) Subretinal band (*white arrow*) with suspected *Toxocara canis* organism (*red circle*)

Among patients with noninfectious uveitis, the risk of RD is 1 %. Pars planitis, when untreated, can develop TRDs [37, 38].

In dealing with these detachments, whether RRD, TRD, or combined detachments, a wide instrumentation is extremely helpful in facilitating repair. A standard three-port vitrectomy may be used. A thorough vitrectomy with elevation of the hyaloid and scleral depression should be performed. The hyaloid, which tends to be very adherent, should be shaved out as anteriorly as possible, paying particular attention to the margin of healthy and necrotic retina. For these complicated cases, 20-gauge vitrectomy still may be the preferred gauge due to the widest array of instrumentation for repair; however, nowadays the gauge choice may be mostly of surgeon preference, as smaller gauge (such as 23 and 25 gauge) instrumentation and variety have become more plentiful. These smaller gauges may also be better for dissection of membranes. On the other hand, smaller gauges may have higher infusion turbulence and if using perfluorocarbon (PFO) may lead to retained or subretinal PFO (Fig. 3.2).

Intraoperative complications are increased in uveitis. Careful attention is required to prevent creating retinal holes if instruments are passed through pars plana exudates and posterior breaks during peeling of densely adherent hyaloid and membranes. Attention to tangential peeling rather than anterior-posterior movements may be helpful in preventing unwanted breaks.

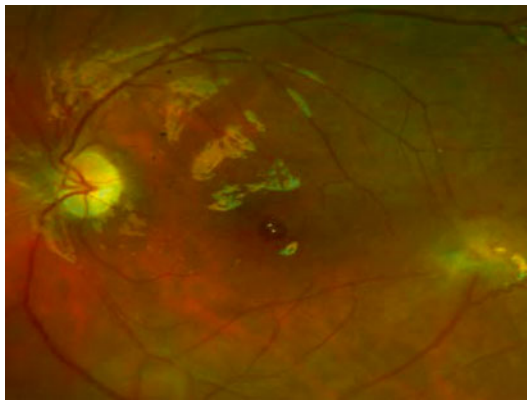

Fig. 3.2 Retained perfluorocarbon bubble after 23-gauge surgery for repair of a retinal detachment secondary to acute retinal necrosis

Removal of the tractional membranes can be time-consuming and tedious. Some surgeons find staining techniques, such as ICG and brilliant blue, helpful. Kenalog, unless in a noninfectious eye, should be avoided for visualization of the membranes. A bimanual technique may be employed with the help of chandelier lighting. Using PFO may also be useful for applying countertraction while completely the vitrectomy or peeling membranes. If traction remains, retinectomies and retinotomies may be employed. For retinectomies, an endodiathermy edge is created posterior to the traction and atrophic retina into healthy retina and cut. The retina is then treated with endophotocoagulation with several rows. Care should be taken to diathermize blood vessels to avoid excessive bleeding. Cryotherapy can exacerbate inflammation and should be avoided. Scleral buckles may be helpful for peripheral support. Silicone oil is the preferred tamponading agent and remains for at least 3–6 months and sometimes indefinitely (Fig. 3.3).

Removal of subretinal bands can also be arduous and time-consuming. Only those bands causing traction should be removed. Those that are too dangerous to remove may be relieved with the help of a scleral buckle. When they do need to be removed, subretinal bands, such as those seen in toxocariasis TRD (Fig. 3.1), can be a major obstacle. Cautery directly over the band can allow for access for subretinal removal, but the angle for removal may be awkward. Also, by dissecting the band, it may be more difficult to remove. Creating an opening adjacent to the band allows for access as well as use of the tautness of the band to facilitate removal, with or without a bimanual technique (i.e., hand-over-hand extraction). Another technique is to diathermize openings on either side of the subretinal band and using a bent pick to gain access under the band for exposure and removal. Once the band has been externalized, a gentle hand-over-hand technique with two forceps (with chandelier lighting) can be used or a forceps and lighted pick for gentle extraction of the band. Once the retina is flat, laser should be applied to the areas of the tears if possible (Fig. 3.4). If this is not possible, such as

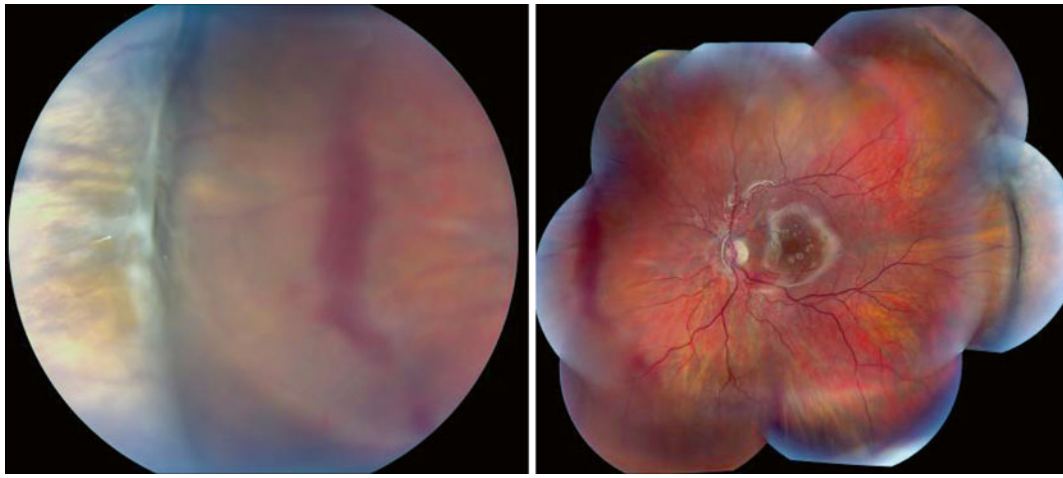

Fig. 3.3 Postoperative fundus photographs of the patient in Fig. 3.1 demonstrating (**a**) scleral buckle with residual hemorrhage in the area of the removed subretinal band and (**b**) flat retina under silicone oil

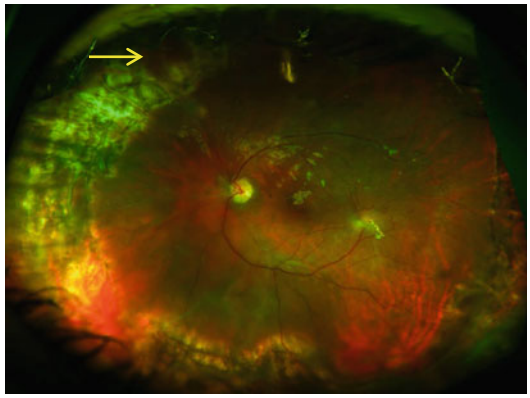

Fig. 3.4 Postoperative fundus photograph of a patient s/p PPV/SO for repair of a retinal detachment secondary to acute retinal necrosis under silicone oil. Laser surrounding the tear (*yellow arrow*) and posterior to the necrotic retina

in cases with necrosis, laser is usually recommended at the posterior edge of the healthy and necrotic retina to secure the retina.

3.3.2.2 Hypotony

Selected cases of hypotony due to uveitis are amenable to surgical therapy, especially those in which irreversible damage to the ciliary processes has not occurred. Chronic uveitis can lead to the development of cyclitic membranes and hypotony. Should anti-inflammatory therapy fail to reverse hypotony, preoperative assessment of the ciliary body with ultrasound biomicroscopy (UBM) is helpful in identifying the presence or absence of the ciliary processes and the location and thickness of the epiciliary membranes. A thorough pars plana vitrectomy with 360-degree scleral indentation, vitreous base dissection, and bimanual epiciliary membranectomy may affect a sustained rise in intraocular pressure with improved vision in eyes with intact ciliary processes. Endoscopy may be helpful to better visualize the ciliary processes and facilitate removal of the membrane. In those with atrophic ciliary processes, silicone oil may be helpful in preventing phthisis [39, 40].

3.3.2.3 Endophthalmitis

In the Endophthalmitis Vitrectomy Study, those patients who presented with light perception and had an immediate vitrectomy had better visual outcomes when compared to those with light perception who had a tap only [17]. In these cases, surgical invention should not be delayed to control inflammation. Of course, the patients with vision of hand motions or better did not see the same benefit with immediate vitrectomy. If the endophthalmitis is not postsurgical, whether a tap or vitrectomy is performed, obtaining cultures is important, especially if patients do not appear to be responding to the initial therapies. Here, a good initial clinical workup and judgment are helpful in directing therapy as well.

3.3.3 Prognosis

Vision function after uveitis-associated RDs is guarded. Prognosis is generally poor due to a high rate of PVR and ocular inflammation reactivation, with 70 % of the eyes with <20/200 vision if surgical intervention occurs during active inflammation [41]. While a final reattachment rate of 88 % was achieved using either scleral buckling or vitrectomy techniques, 67 % had a final visual acuity worse than 20/200. This may not only be due to the complication requiring but secondary to the underlying inflammatory cause, especially if optic nerve damage is present.

Conclusion

Complicated retinal detachments are frequently encountered in patients with posterior uveitis. These may be successfully repaired in a high percentage of cases with careful vitrectomy and proper long-term tamponading agents [42, 43]. Tractional complications not infrequently seen in patients with ocular toxocariasis, toxoplasmosis, and pars planitis are best managed with vitrectomy and facilitated with bimanual membrane dissection [44].

Vitrectomy in uveitis is indicated in the diagnosis and/or correction of surgical posterior segment uveitic complications, such as epiretinal membranes, recalcitrant macular edema, non-clearing vitreous opacities, and more difficult complications like retinal detachments and hypotony. Special circumstances associated with uveitis patients alter surgical planning. The need for control of inflammation pre- and postoperatively is imperative. Though scleral buckles may be acceptable for some rhegmatogenous detachments in uveitis affecting the posterior segment, vitrectomy appears ideal for repair and to possibly reduce the chance of postoperative complications. Surgery for hypotony in uveitis with ciliary body membrane stripping has been reported but is unlikely to be successful if the cause is atrophy of the ciliary processes. A thorough discussion with the patient detailing the guarded prognosis is important as well as managing expectations and controlling inflammation.

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Management of Open Globe Injuries

4

Ferenc Kuhn and Robert Morris

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F. Kuhn, MD, PhD (✉)
Clinical Research, Helen Keller Foundation, Birmingham, AL, USA

International Society of Ocular Trauma, Birmingham, AL, USA

Milos Eye Hospital, Belgrade, Serbia

Zagorskiogo Eye Hospital, Cracow, Poland
e-mail: fkuhn@mindspring.com

R. Morris, MD
Helen Keller Foundation, Birmingham, AL, USA

There are relatively few true emergencies in ophthalmology; an eye with an open globe injury (OGI) should be considered as one. Although a delay in its treatment does not always hinder the prognosis, in the vast majority of the cases it does – and whether the former or the latter applies is in most cases impossible to know at the time: even an injury with a small, innocent-looking wound may develop endophthalmitis.

This chapter provides a blueprint for the treatment of a patient with an OGI. While certain details of the actual surgical intervention/s are provided here, for lack of space the reader interested in further details should consult textbooks dedicated to the topic.

4.1 Strategy

No pathology and no surgery for that pathology should ever be considered "routine", and this is especially true in the case of an OGI. "Routine" implies that one case is just like any other, and the management of the condition requires mostly applying the dexterity of the surgeon's healing hand, rather than the power of the thinking brain. Consequently, the attending ophthalmologist must make a number of conscious decisions before any intervention is made.

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4.1.1 Triaging: Urgency

Upon first seeing the patient with an OGI, the ophthalmologist must make an instant decision whether immediate/emergency surgery is needed. Such an intervention is called for if there is a high risk of an *expulsive choroidal hemorrhage* (ECH); the significance of this condition lies in the fact that irreversible loss of vision and even eyeball can occur in seconds. The ECH risk is greater if:

- The systemic blood pressure is elevated.
- The patient is on anticoagulant therapy (warfarin, aspirin etc.).
- The wound is large, especially if caused by a rupture.
- The intraocular pressure (IOP) is elevated.
- There is external pressure on the eyeball (which may come from an orbital or lid hemorrhage, the patient's own hands, or a heavy-handed physical examination by an ophthalmologist).
- The patient is not cooperative (child, mental retardation).

A careful consideration of all these risk factors is necessary to make a decision whether emergency wound closure and/or systemic intervention (lowering the systemic blood pressure, anti-anxiety medication) is necessary; if surgery is delayed, as a minimum the eye must be covered with a hard shield and the proper behavior must be explained to the patient. This involves:

- Reassuring words that all will be done to restore as much vision as possible
- The importance of avoiding any external pressure on the eyeball
- Refraining from any activity that can increase the IOP (Valsalva maneuvers such as coughing, or bending down)

A second reason for emergency intervention is *endophthalmitis*, either already present or if its risk is high. Although it is not as urgent an indication as an ECH, a virulent pathogen such as *Bacillus* can result in the irreversible destruction of an otherwise intact retina within a few hours. While taking a detailed history may be helpful in assessing the endophthalmitis risk, it is far from being a perfect measure of the prognosis (see below).

In most other cases, the decision whether to intervene (wound closure) need not to be taken immediately, allowing the ophthalmologist to carefully consider all other factors listed here.

4.1.2 Evaluation: Diagnosis

First, it is necessary to take a *history* of the event. It does not have to be comprehensive but must address a few key points.

- What happened?
- When did it happen?
- How did it happen?
- Where did it happen (possibility of soil contamination, a significant risk factor for a fulminant infection)?
- What was the object that caused the injury? Was it sharp or blunt?
- Is there, and if yes, how severe, visual loss? Its change since the injury?
- Any pain at the time of the injury and since?

As appropriate, a *systemic history* must also be taken to determine whether trauma to other parts of the body may also have occurred since they may have to take precedence over the eye injury. Systemic conditions (medications, see above) that can influence the decision whether and when to operate should also be asked for.

In children, it is rather common that the version of history elucidated is incomplete or incorrect as the child tries to hide something inconvenient or illegal. (Hence the need for a witness if one can quickly be found. The witness should not be one who may also have an interest in distorting the truth, such as a babysitter involved in the occurrence of the injury.)

An *inspection* of the face follows, to look for obvious signs of the trauma. A penlight is very useful in this, and the findings may result in the asking of additional questions regarding the event.

A *slit lamp* examination is almost always necessary. An important caveat is to avoid exerting pressure on the eyeball so as to examine it. A severe lid hemorrhage may make it impossible to visualize the eyeball, and forceful attempts to open the lids can cause (further) prolapse of intraocular tissues, even an ECH. Otherwise, the slit lamp offers invaluable information about the pathologies caused by the injury, including the

wound/s and up to the anterior vitreous. Depending on the condition of the anterior segment, use of a 90-degree lens permits viewing of the retina as well.

If the pupil is (can be) reasonably dilated and the media are clear, the *indirect ophthalmoscope* allows at least a partial examination of the retina. The information obtained via ophthalmoscopy can be superior to that gained by the slit lamp.

The *IOP* should not be measured since it typically involves at least some pressure on the eye, and its value is rather irrelevant: an elevated IOP does not preclude the possibility of an open globe and, conversely, a low value does not necessarily mean that the eye is open.

It may be useful or necessary to perform *ultrasonography* (it is contraindicated if pressure on the globe cannot be avoided) or radiologic tests (*CT*, *MRI*); these, however, may have to be deferred until after the wound has been sutured. Furthermore, all of these tests can yield incorrect information such as suggesting a retinal detachment when it is not present or presence of an intraocular object when it is in fact extraocular. The ophthalmologist must therefore maintain a critical view of all test results.

The primary goals of the entire evaluation process is to determine whether the injury is indeed open globe, how great the risk of endophthalmitis is, and whether an intraocular foreign body (IOFB) is present. In certain cases it is impossible to establish whether an OGI has occurred: the entrance wound may be too small or posterior to detect (even though an IOFB is present) or the conjunctiva may be intact over a scleral wound. Such an *occult rupture* should be suspected if:

- The injury was caused by a blunt object.
- The sclera is hidden under a thick hemorrhage.
- On (very delicate!) palpation, a scleral step sign is felt.
- The pupil is peaking (pointing toward the site of capture of the anterior uvea in the scleral wound, Fig. 4.1).
- The lens is lost and there is a bulge under the conjunctiva (Fig. 4.2).
- There are streaks in the vitreous, pointing toward the incarceration of the gel into the wound (Fig. 4.3).

Fig. 4.1 Peaking pupil in a case of occult rupture. The shape of the pupil points toward a scleral (limbal) wound at 6 o'clock

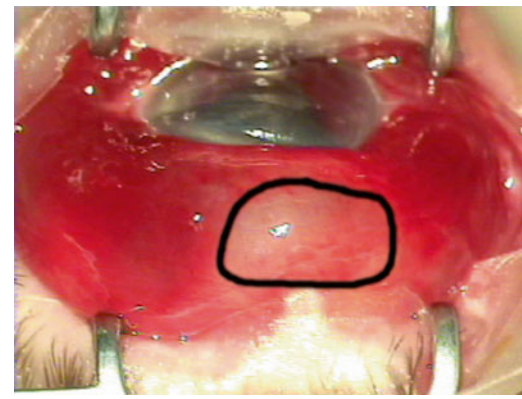

Fig. 4.2 Lens extrusion in a case of occult rupture. The *black line* indicates the area of a conjunctival bulge. The large area of thick subconjunctival hemorrhage is another suspicious sign for an occult rupture, even if the scleral wound itself is not visible

In addition, there may be indirect signs supporting the presence of an occult scleral rupture:

- There is no red reflex (due to a severe vitreous hemorrhage, which is very common in a ruptured eye).
- There is loss of the iris (extruded – although rarely under the conjunctiva).

If the presence of an occult rupture cannot be excluded during the evaluation, the eye should be explored, and as a minimum, the conjunctiva opened in the operating room to examine the sclera.

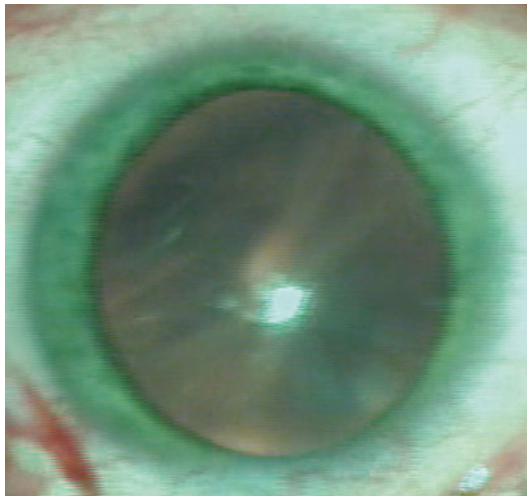

Fig. 4.3 Vitreous streaking in a case of occult rupture. Although the trauma occurred several weeks earlier, the telltale signs of the structure of the anterior vitreous make the presence of a (spontaneously closed) scleral rupture highly likely. Such a contraction of the incarcerated vitreous represents a high risk of tractional retinal detachment

Finally, two words of general caution. First, if history and the findings contradict each other in an adult, it is safer to assume that history is correct; in a child, the opposite is true. Second, once it has been established that the injury is open globe, the examination should be limited to establishing major facts such as how urgent the primary surgery is and whether it should be comprehensive. Trying to determine fine/r details of the tissue pathologies risks causing an ECH – this author saw two such disasters at the slit lamp when the young, inexperienced ophthalmologist ignored the warning to stop trying to force the lids open.

4.1.3 The Eye with No Light Perception Vision

For many surgeons, no light perception (NLP) in the trauma setting indicates an irreversible condition (i.e., no reconstructive surgery is justified). For some surgeons this is compounded by the (assumed) threat of legal action should sympathetic ophthalmia subsequently occur (see below).

The prognosis of an injury is indeed much worse if the visual acuity is NLP versus light perception (LP): improvement in the database of the United States Eye Injury Registry (USEIR) has been identified in 14 % in the former and in 84 % in the latter category. However, the improvement rate (ranging from LP to 20/40) from NLP is much higher among surgeons who are not only experienced in the management of severe trauma but also dedicated to intervene and to do it early [1].

Here is a brief list of recommendations for the management of a patient with an eye injury that was severe enough to cause NLP vision (the recommendations are valid in any case but "especially so" if LP was lost):

- Confirm the NLP status using the strongest light of the ophthalmoscope (this is done not because the findings would influence the decision-making process but because it does impact the prognosis and the way the patient is counseled, see below).
- Counsel the patient about the options (Table 4.1), the risk and symptoms of sympathetic ophthalmia, the postoperative course, etc., and make a decision regarding treatment.
- Determine if you, the attending ophthalmologist, has what it takes to perform the reconstructive surgery (Table 4.2).
- If the answer is "no" to the question above, refer the patient immediately to a facility where emergency surgery can be performed; if the answer is "yes," consider comprehensive primary surgery (see below) or within the first 4 days.

4.2 Endophthalmitis

A purulent infection following open globe surgery is usually recognized before irreversible damage occurs, partly because the organism is not likely to be very virulent, but also because the symptoms/signs are rather straightforward. In a traumatic setting (OGI) neither may be true: the endophthalmitis can lead to loss of function in a matter of hours, and phthisis eventually follows. Furthermore, the symptoms (pain, decreased vision) can be caused by the accompanying tissue pathologies, and the signs such as hypopyon, loss of red reflex, endophthalmitis retinopathy, etc.,

Table 4.1 Management options for an injured eye with NLP vision

Option	Comment
Enucleation (primarily or within a few days)	In addition to the loss of the eyeball, there is major psychological trauma to the patient. *Death sentence to the eye*
No intervention beyond wound closure ("giving up")	The vision remains NLP and the eye will become phthisical; usually, the younger the patient, the sooner this is expected. *Death sentence to the eye*
Primary wound closure, followed by reconstructive surgery when the cornea becomes sufficiently clear	By the time reconstructive surgery can be performed, the intraocular damage becomes, with very rare exceptions, irreversible; the vision remains NLP and the eye will become phthisical. *Typically, death sentence to the eye*
Primary wound closure, followed by reconstructive surgery, to the extent the cornea allows it, around postoperative day 10–14	By this time the intraocular damage becomes, with very rare exceptions, irreversible; the vision remains NLP and the eye will become phthisical. *Typically, death sentence to the eye*
Early reconstructive surgery (primarily or within the first 4 days postinjury)	Offers the best chance of restoring some vision or at least preserving an anatomically acceptable eyeball. Requires the full armamentarium a vitreoretinal surgeon can offer, including the use of the temporary keratoprosthesis. *As a minimum, both patient and surgeon are confident that everything that could be attempted to save the eye/vision has been done*

Table 4.2 The logistics/infrastructure necessary to perform "extreme" reconstructive surgery for a severe eye injury

Item	Comment
Surgeon	Expertise and experience in *all* procedures *both* for anterior and posterior segment pathologies and dedication so as not to give up as long as there is even minimal hope. It is unacceptable if a surgeon who otherwise does only anterior segment work halts surgery halfway done because he is not knowledgeable in techniques required in the posterior segment or, worse, ventures behind the posterior capsule without proper expertise
Support staff	Knowledgeable in any type of eye surgery as well as in the workings in an actual operating room (able to locate and operate any equipment, instrument, material)
Facility	Open 24 h/, 7 days a week, and offering any and all equipment, instrument, and material; can keep the patient in-house as long as the condition requires; all type of support is available (consultation, culturing, etc.)
Financial background	Surgery for a "hopelessly" injured eye is not discouraged/forbidden by the administration, nor does it take away opportunity for surgery on an eye with better prognosis/elective surgery ("either this-or that patient/eye")

may be masked by blood, fibrin, cataract, etc. – or not present at all (Fig. 4.4a).

The diagnosis of traumatic endophthalmitis is an indication for emergency vitrectomy. A meticulous anteroposterior approach is required, listed below:

- Cornea: scrape the epithelium, even in diabetics; the always-present edema would otherwise prevent completing the most crucial part of the task, which is to clear the vitreous cavity, especially posteriorly.
- Anterior chamber: irrigate to remove the debris, pus, and blood. Use careful suction with a blunt cannula or the vitrectomy probe and/or use microforceps to remove also all the fibrin – in children it may have to be done repeatedly as it can reform intraoperatively. The angle must also be cleaned. Up to this point it is best to use an anterior chamber maintainer to keep the eye pressurized; the pars plana infusion may have been placed earlier (if surgery in the posterior segment is to be carried out in the same setting) but should not be opened until its tip is made visible during vitrectomy.
- The pupil must be dilated; if necessary, retractors must be used.
- If the crystalline lens is present, it may require removal, even when clear. The intraocular lens (IOL) may be preserved, but its anterior surface must be cleaned (if suction – see above – is not sufficient to achieve a clear surface, a

small piece of wet cotton can be grasped with the microforceps and used as if doing window-cleaning). The posterior capsule has to be opened with the cutter – the larger the opening the better – and the irrigation fluid must be allowed to circulate the entire capsular bag.

- The vitreous cavity must also be cleaned in a meticulous anteroposterior direction (Fig. 4.4b), but the vitrectomy probe should be kept rather close to the visual axis and not approach the retinal periphery until late in the process, and even then very carefully. (A sample of the undiluted vitreous should be taken initially and sent for culturing.) The golden rule is to be rather aggressive posteriorly (to clean the macula as much as possible) but remain rather conservative at the vitreous base. The thick, nontransparent vitreous may prevent visualizing the peripheral retina, and it is thus easy to cause a break there; while this does not necessarily have as tragic consequences as leaving pus on the macular surface, nor is it desirable.

The retina is fragile (endophthalmitis retinopathy) due to the organism's toxins, enzymes, and the body's immune reaction; if visibility allows, it is best to use a contact lens to clean the retinal surface. The posterior vitreous is almost never detached (Fig. 4.4c), and the goal is to detach it – but it must be done only to the extent consistent with safety. The retinal surface should be vacuumed with the flute needle so as not to leave purulent material behind (Fig. 4.4d).

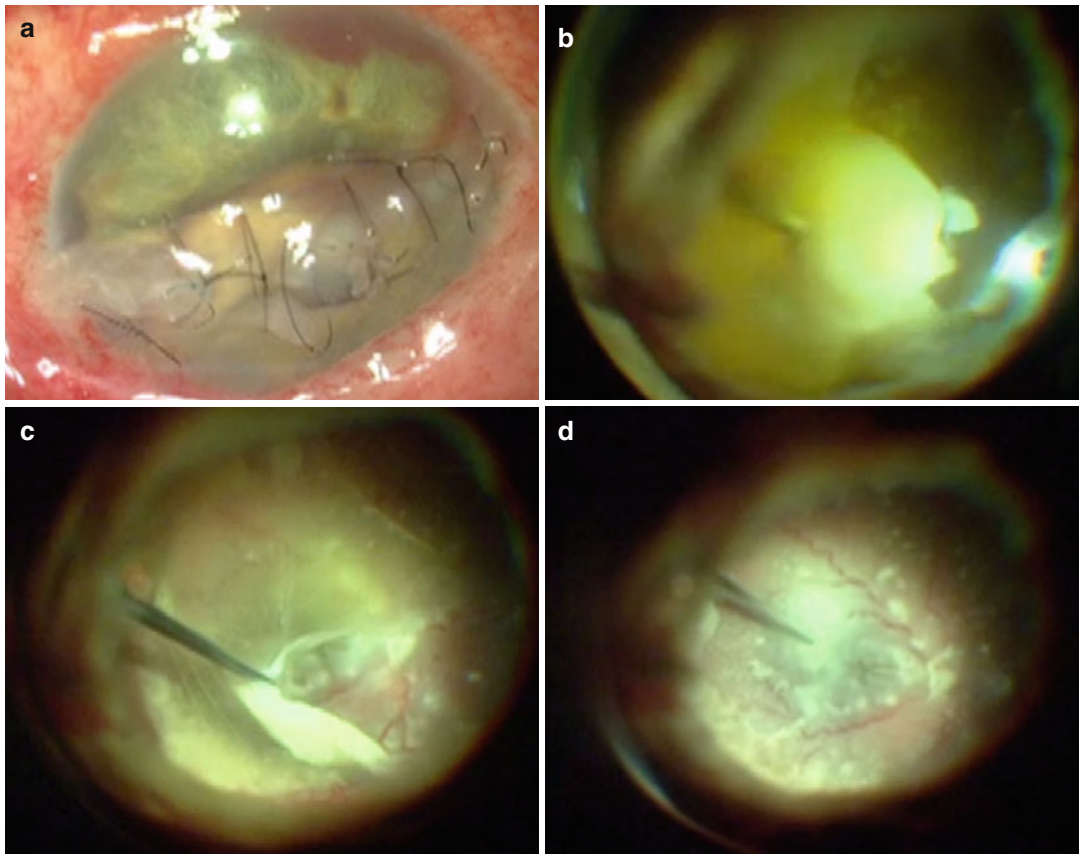

Fig. 4.4 Traumatic endophthalmitis. (**a**) This young man was injured in a car crash 3 weeks earlier. The cornea is poorly sutured, but it cleared up sufficiently to allow visualization of the anterior chamber. There is no hypopyon or any other sign of endophthalmitis, nor did the patient experience pain at any time after the injury. (**b**) During vitrectomy (using a temporary keratoprosthesis) a purulent vitreous is found. (**c**) The (purulent) posterior hyaloid is still attached. (**d**) Underneath the posterior vitreous cortex, a macular hypopyon is hidden

If the retina has been injured by either the disease or the surgeon (necrosis, break, detachment), the vitreous cavity must be irrigated by a fluid containing antibiotics (2 mg/0.1 ml of both vancomycin and ceftazidime) and corticosteroids (0.4 mg/0.1 ml of dexamethasone); a more diluted concentration is ineffective. Silicone oil should then be implanted and at the end of surgery antibiotics/corticosteroids injected into the oil (one-third of the usual concentration). It is advisable to also use proper systemic antibiotics therapy.

4.3 Counseling: Sympathetic Ophthalmia

Unless there is an absolute emergency such as an ECH, or the patient is unconscious or mentally retarded, or a minor with no guardian is readily available, it is best to explain to the patient the details of the condition of the injured eye and all the available management options, their risks, and advantages, and let the patient choose the therapy.

The risk to the fellow eye should always be discussed – but never in a way that discourages the patient from selecting the "try the reconstruction" option. Figure 4.5 shows a case (thick-framed box) and two very different kinds of counseling. While both are truthful, the patient informed by the words seen in the shaded box on the left is likely to elect enucleation. The patient who receives the information shown in the box on the right will choose reconstruction. The first author, who counsels his patients in the spirit of the latter, has never encountered a patient who would have chosen "just-to-be-on-the-safe-side" removal of the globe.

The golden rule is that sympathetic ophthalmia should always be discussed with the patient, but it should never drive the selection of the management [2].

4.4 Management Plan (Current vs. Future Issues)

Based on the history, the findings during evaluation and the logistical issues (Table 4.2), and the decision after counseling of the patient, the surgeon must design a treatment plan. The primary

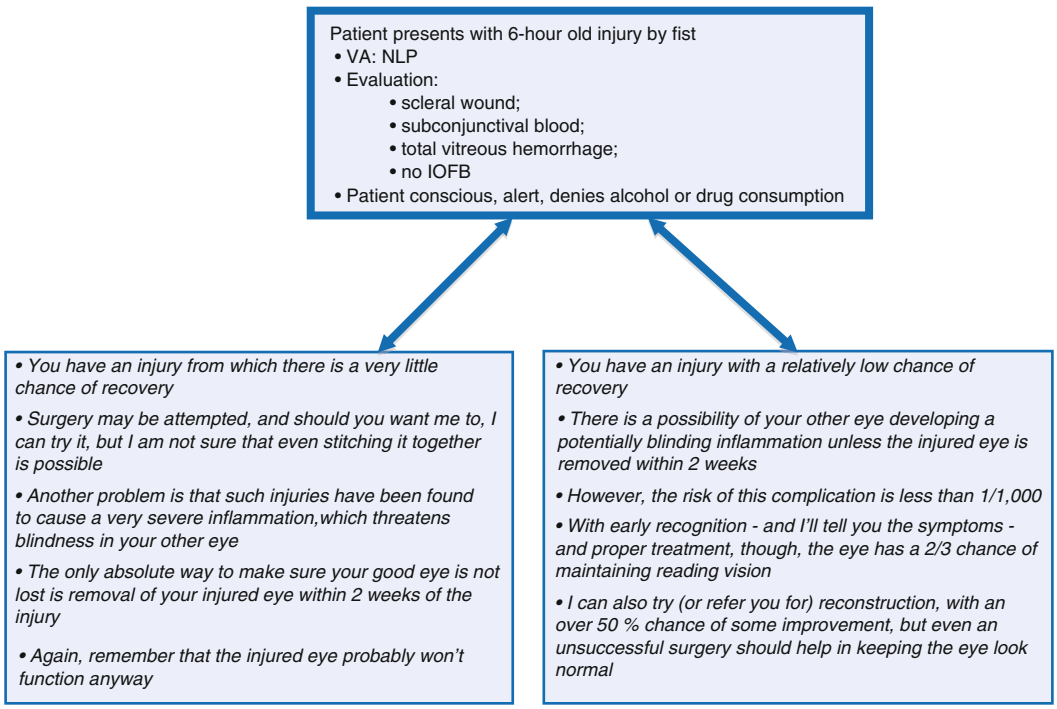
Patient presents with 6-hour old injury by fist
• VA: NLP
• Evaluation:
• scleral wound;
• subconjunctival blood;
• total vitreous hemorrhage;
• no IOFB
• Patient conscious, alert, denies alcohol or drug consumption
• You have an injury from which there is a very little chance of recovery
• Surgery may be attempted, and should you want me to, I can try it, but I am not sure that even stitching it together is possible
• Another problem is that such injuries have been found to cause a very severe inflammation,which threatens blindness in your other eye
• The only absolute way to make sure your good eye is not lost is removal of your injured eye within 2 weeks of the injury
• Again, remember that the injured eye probably won't function anyway
• You have an injury with a relatively low chance of recovery
• There is a possibility of your other eye developing a potentially blinding inflammation unless the injured eye is removed within 2 weeks
• However, the risk of this complication is less than 1/1,000
• With early recognition - and I'll tell you the symptoms - and proper treatment, though, the eye has a 2/3 chance of maintaining reading vision
• I can also try (or refer you for) reconstruction, with an over 50 % chance of some improvement, but even an unsuccessful surgery should help in keeping the eye look normal

Fig. 4.5 Counseling options. See the text for more details

decision is whether the patient is to be referred or the attending ophthalmologist will perform the intervention.

The plan involves much more than deciding "how to do the surgery" because it must answer two much more basic questions: the one regarding timing and one regarding staging (the question of emergency surgery has already been discussed above). The plan is not restricted to the first surgery but looks at the eye (person) as a whole: the plan incorporates every aspect of the road to as full anatomical and functional recovery as possible. It is therefore important to plan for the number of surgeries that will or may become necessary.

In the vast majority of the cases the wound must be sutured (see below), and it is usually advisable to do this as early as possible. The often-raised question is whether a wound that is small (a few millimeters long) should be closed late evening upon patient arrival or it can safely be deferred until the next morning when conditions in the operating room may be more ideal – but also, to be honest, because it is much more convenient to the surgeon.

The answer is: yes, in most cases it can be deferred. However, it is not always possible to tell in advance which are the cases where deferral is acceptable and in which cases will an ECH or endophthalmitis develop. The general rule therefore should be: better safe than sorrow, close the eye upon patient presentation and not wait until the next day. The surgeon who does not follow this rule better have a good excuse why not (for legal as well as medical reasons).

A wound that is properly sutured (see below) still leaves open the question about the rest of the eye – in the vast majority of cases there are other pathologies ranging from hyphema to retinal detachment. If these pathologies involve only structures anterior to the vitreous, the surgeon may still defer removal of an injured lens and IOL implantation. Typically, there is no harm if the reconstructive surgery is delayed for several weeks.

If, however, the posterior segment is also involved, it is crucial not to wait too long. The final outcome of the injury is mainly determined by two tissues: the ciliary body and the retina. (The third, also crucial, the optic nerve, is rarely involved.)

Since the late 1970s, it is widely accepted not to wait with the vitrectomy for more than 2 weeks [3]. Waiting that long made sense in the pioneering era of vitreous surgery; today, however, the rationale for this delay must be questioned.

The explanation for the delay was partly based on the experimentation referenced above: no difference in the risk of scar formation and retinal detachment was found whether surgery was done early or delayed for 2 weeks. The delay was supported by clinical reasoning as well: the risk of an ECH is indeed higher in the very early postinjury period, and the posterior cortical vitreous has also been assumed to detach by the time of the delayed surgery.

While the risk of a major intraoperative hemorrhage is indeed higher if the vitrectomy is performed during the primary surgery, the posterior hyaloid does not detach in 2 weeks in these typically young patients (Fig. 4.4c); at most a posterior vitreoschisis develops. Conversely, the major advantage of a primary comprehensive surgery (wound closure, reconstruction of the anterior segment, and vitrectomy) is that it can prevent the development of retinal detachment and proliferative vitreoretinopathy (PVR) as well as phthisis. This author has seen retinal detachment being present as soon as a few hours postinjury and inoperable PVR with a closed funnel by postinjury day 12.

The risk of an intraoperative ECH is real. Should it occur, it is rare that its source can be localized. The closed-globe environment must be maintained (any open wound or incision immediately closed, if necessary by the surgeon's finger pressing the wound lips together) and the vitreous cavity filled with air at high pressure – but making sure that the infusion cannula is not under the choroid [4]. Usually it is not advisable, or even possible, to finish the operation; it is better to delay it until the eye "cools down" – again, intense topical corticosteroid therapy is needed.

An additional issue to be discussed when primary (or very early) vitrectomy is performed is the risk of reopening of an unsutured posterior wound. While it is indeed an issue to keep in

mind, it is also important to understand that scleral wounds close rather firmly rather early. As long as the wound is not too large and the surgeon does not manipulate this portion of the wound while keeping the intraoperative IOP in check (not exceeding 25–30 mmHg), the reopening risk is sufficiently minimal not to by itself justify delaying the vitrectomy.

A decent compromise between the typical 10-day delay and primary comprehensive surgery is a staged surgery with the wound closure (and certain anterior segment manipulations such as hyphema removal) being done as soon as possible, followed by intense topical corticosteroid therapy. The comprehensive reconstruction is done within the first 4 days. Such staging/timing usually avoids the risk of hemorrhage while allowing the prevention of catastrophic posterior segment problems and irreversible ciliary body scarring.

4.5 Combined Anterior and Posterior Segment Trauma (Temporary Keratoprosthesis Vitrectomy)

The corneal injury may be so bad – or the initial closure so poor (Fig. 4.6) that it is impossible to perform proper vitrectomy. This leaves the surgeon with a few bad choices (Table 4.1) and with two superior ones.

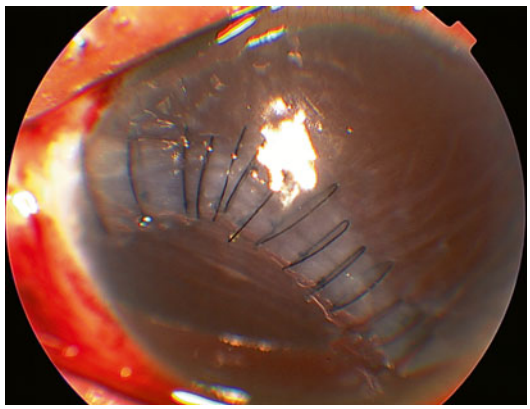

Fig. 4.6 A poorly sutured corneal wound. Although the wound is watertight, the suture were put in randomly, as evidenced by their spacing and distance from the wound edge

If the surgeon is well versed both in ocular traumatology and endoscopy, endoscopic vitrectomy may be attempted [5]. In most cases, however, temporary keratoprosthesis (TKP) vitrectomy is the favored option because it allows bimanual surgery with excellent visibility, and the injured cornea needs replacement anyway. (If no graft is available, either the TKP is left in place or the original cornea is resutured until a suitable donor cornea becomes available.)

It is not possible here to detail this complex and occasionally multi-hour surgery (see reference [6] for all additional details), but a blueprint is provided below, reflecting the approach of the first author).

- Close the corneal/scleral wound properly.
- Place a pars plana infusion but do not open it. An anterior chamber maintainer may be placed later if necessary, once the TKP device is in place. If the eye is soft, use a 27 g needle to restore the IOP.
- If the wound was closed by someone else and is leaking or the corneal sutures are unlikely to resist the unavoidable pressure (outside the area of the planned trephination) during the remaining part of the surgery, resuture the wound appropriately.
- Select the size and location of the trephination. The general advice for the size is: the larger the better; if the keratoplasty has to be repeated, it is better to retrephine inside, rather than outside, the previous one. The actual size is determined by the size of the available TKP device. The trephine is ideally 0.5 mm larger than the barrel of the TKP – this allows easy insertion without intraoperative leakage, due to the sutures holding the TKP.

The location is determined by two factors: the pathology (wound) and the visual axis. The trephination does not have to concentric, although for restoring the original dome shape of the cornea this would be ideal.

- Perform just enough manipulations open sky so as to allow visual confirmation of the pars plana infusion cannula not being under the retina. Keep the time of the globe being non-

pressurized to the minimum, to reduce the risk of an ECH. Maneuvers to clean the iris surface, remove lens remnants, etc., are easier and faster open sky – but riskier than done with the TKP in place. The surgeon may elect nevertheless to do more manipulations before the TKP is sutured in – but must be aware of the risk this decision involves. One thing that should not be done at this stage is suturing of the iris so that the pupil remains as large as possible. (A nondilating pupil requires retractors.)

- The TKP is sutured in place. If the Landers design is used, the 10-0 nylon sutures must first go through the TKP, then the cornea (sclera).
- All intracameral blood and fibrin, any pupillary membrane, the injured lens, etc., are removed. Both lens capsules must be removed.
- All necessary work is done in the posterior segment (vitrectomy, including detachment of the posterior hyaloid, retinal reattachment, laser, etc.).
- With scleral indentation, the ciliary body is thoroughly cleaned. This may require the use of both blunt (spatula) and sharp (scissors) instruments; because of the delicacy required when working over the ciliary processes, which can cause profuse bleeding if injured, it is best if the surgeon does the indentation himself. All capsular remnants, fibrinous tissue, blood, etc., must be removed so that the ciliary processes are completely free and clean.
- If there is iris or ciliary body detachment, this must be sutured according to the surgeon's favorite technique.
- If silicone oil is used, it is best to do the exchange after the cornea has been sutured in – provided the graft is in good condition (clarity). If not, and it is likely that even with the BIOM (Oculus GmbH, Wetzlar, Germany) it would not be possible to achieve a 100 % silicone oil fill, the implantation may be done at this stage – but it is likely that topping off the oil at the end of surgery may be needed.
- If the iris must be sutured, this is the time to do it – but do not make the pupil too small.
- Do not implant an IOL. If there is indication to do so during the course of the next few months (stable retina, good IOP, decent visual function), an IOL can be placed as the last part of the eye's rehabilitation (this author favors the iris-clip IOL to one sutured to the sclera).
- The TKP is removed and the donor cornea implanted (with full-thickness sutures, see below).
- Consider leaving corticosteroids intravitreally.

4.6 Selected Surgical Issues

This is far from being a comprehensive list, nor are all details of each pathology included here; for further information, the reader is referred to the appropriate textbook.

4.6.1 Wound Closure

4.6.1.1 Corneal Wounds

- Before any suture is introduced, the wound must be cleaned of any debris, fibrin, foreign material, prolapsed iris, and/or vitreous.
- Not all wounds require suturing; a very small, self-sealing wound may need to treatment at all, or, alternatively, cyanoacrylate glue and/or a bandage contact lens may be sufficient. Caution is to not use glue and suture together; if the glue gets in contact with the suture, it cannot release.
- The question often arises about who should suture the wound (the "when" has already been discussed earlier). The answer is on one hand simple: whoever can do an ideal job. This sounds obvious, but in the era of phacoemulsification and transconjunctival vitrectomy, the teaching of even conjunctival suturing is neglected, much less corneal wound closure. The suturing of a traumatic corneal wound is too often done by the least experienced resident, who has never been trained to suture and has no idea about needle types or basic suturing rules.

Should posterior segment surgery be also necessary (over half of the cases), there is one advantage having a vitreoretinal surgeon do the closure: he is well aware of the need to reach maximum corneal transparency as soon as possible (see below).

- Making the wound watertight is a conditio sine qua non; the shape of the cornea must also be restored to be as close to the normal (dome) shape as possible, and the edema allowed to clear rapidly so that it does not interfere with surgery on the posterior segment.
- Sutures should never be introduced at random (Fig. 4.6): their placement requires expert planning. Below are the most important rules guiding the process:
  - *The suture material*: 10-0 nylon.
  - *The type of suture*: Interrupted or running. Both have their own advantages and disadvantages, but in the cornea the rule is to use running sutures in the limbus, especially if the wound is long (~over 3 mm). In all other locations running sutures must not be used since they flatten the corneal dome and result in a shallow anterior chamber as well as change the eye's refractive power.
  - *The order of suture placement*: It depends on the location, shape, and to a lesser extent the length of the wound.

    If the wound is corneoscleral, the first suture is placed at the limbus, where the anatomic matching of the opposing wound edges is most readily visible. The cornea is closed then, followed by the scleral portion. If the wound has an edge (such as a "V" or "Y" shape), this is the site of the initial suture.

    A small, linear wound can be closed following the "50 %" rule: the first suture splits the wound into two equal halves, which are again split in the middle. Larger, transcorneal wounds are closed according to the Rowsey-Hays rule [7]: start in the periphery with large bites on both ends and advance toward the corneal center with progressively smaller bites. If possible, avoid placing a suture at the epicenter (visual axis).
  - *The length of the suture bite*: Unless the wound is oblique (see below), the bites should be of equal distance from the wound edge.
  - *The angle of suture placement*: Perpendicular to the plane of the wound.
  - *The depth of the suture bite*: 100 %. The traditional ("2/3 to 95 % deep") rule was justified when the suture was not atraumatic. The advantage of the full-thickness suture is that it instantly and permanently seals the back of the cornea as well, preventing aqueous access to the stroma. The first author often sees a corneal edema completely disappear by the time the suturing is completed, allowing him to continue with vitreoretinal surgery in the same setting, even permitting fine maneuvers such as removal of the internal limiting membrane. The only place not to use 100 % deep sutures is the limbus to avoid introducing stem cells into the anterior chamber. Finally, while the full-thickness suture does not increase the risk of endophthalmitis when the suture is in place, the risk is high upon suture removal, and this requires proper preparation of the surface (see below).

    The needle should be held perpendicular to the surface as it enters the cornea; once the tip of the needle is in the anterior chamber, the surgeon turns his wrist and advances the needle parallel to the iris plane (without catching it, obviously). When the optimal exit point from the endothelial side is reached on the opposite side of the wound, the hand is turned again, and the needle travels from the anterior chamber toward the epithelium almost vertically.
  - *Viscoelastic use*: The first author almost never uses viscoelastics when suturing a corneal wound. The wound has spontaneously closed beforehand; if suturing is done properly, the aqueous does not escape during suturing; therefore, the chamber is deep enough to avoid iris capture. Should viscoelastic somehow be needed, it should be injected very slowly, and only in a tiny amount (to avoid distorting the wound) and from a distant paracentesis (not through the wound).

– *Preparation of the knot*: The knot must be firm so as not to loosen yet small so that it can be buried (a knot that is left on the surface causes irritation and thus vascularization and is extremely irritant to the patient. Unfortunately, too often even this most basic rule is not followed.)

  One option is to use an initial triple throw; the hands are then crossed and the suture appropriately tightened. This is followed by a second, single throw with the hands turning so that the plane of the suture is now parallel to the wound (perpendicular to the previous throw). This locks the suture, but it is advisable to add a third, also single throw, which is perpendicular to the previous one (parallel to the wound).
– *The tension on the suture*: All sutures work via tissue compression and each create a zone (with the wound-closure efficacy decreasing away from the plane of the suture). These zones must overlap to achieve watertightness. This, however, should not be done by creating too much tension as it distorts the tissue, which is a permanent fault. Making the bites longer is a more physiological option since longer bites – at the same tension – cause more compression.
– *Forceps use*: There is no need to grasp the corneal tissue in order to pass the needle through it. The needle is sharp enough to easily penetrate the cornea without the need for a counter-force; grabbing the cornea traumatizes it and increases its recovery time from the edema.
– *Special cases*

  Oblique wound: To avoid tissue override, the full-thickness suture is placed so that the distance from the wound edge is identical on the external surface on one side to that on the internal surface on the other side (Fig. 4.7).

  Stellate wound: The initial suture is one that is placed horizontally (inside the corneal stroma) at ~50 % depth, incorporating all wound edges. Once tied, this suture is buried deep and will never be removed (Fig. 4.8). This suture brings the edges in contact, leaving the remaining wounds to be closed individually as appropriate (see above).
– *Suture removal*: Sterilize the surface of the eye as if the eye were undergoing surgery or an intraocular injection. This avoids introducing organisms into the anterior chamber as the suture is turned during removal.

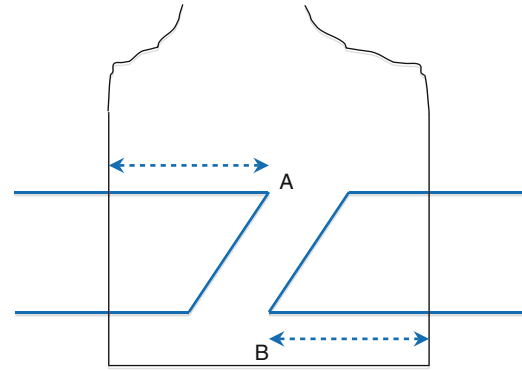

Fig. 4.7 Closure of an oblique corneal wound. The suture is introduced vertically; its distance from the wound edge is the same on the front surface (epithelium) on one side of the wound as the distance from it on the back surface (endothelium) on the opposite side. See the text for more details **A** should be equal to **B**

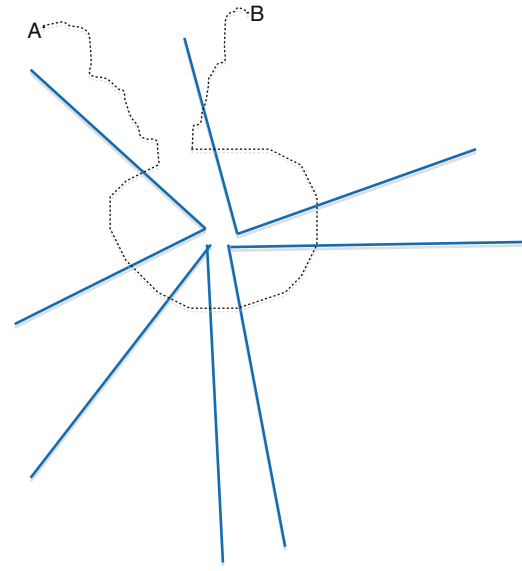

Fig. 4.8 Closure of stellate corneal wounds. The entry point is from inside one of the wound edges into the stroma at 50 % depth; once the needle incorporated all torn corneal tissues by completing the circle, it exits into gaping wound opposite the entry point. See the text for more details **A** is the suture entering, **B** is the suture exiting

4.6.1.2 Scleral Wounds

The primary goal of suturing is to create a watertight wound – without risking an ECH by external pressure (see below). Unlike with corneal wounds, transparency is not an issue; it is therefore not an important issue exactly how deep the suture is.

Remember that the eye may have more than one scleral wound; do a 360-degree peritomy if any doubt exists. This avoids leaving any unrecognized (anterior) wound open. If this happens, the danger is not simply that there is significant tissue incarceration but also that the sclera becomes macerated, which makes its ultimate closure (necessary to perform vitrectomy) much more difficult: cheese-wiring is a real risk.

By the time the surgeon opens the conjunctiva, the wound will have temporarily closed due to tissue prolapse. Care must be taken to avoid, especially if the wound is large, a sudden drop in the IOP, which in turn may cause an ECH. Any wound toilette therefore requires extreme caution. If the vitreous prolapse appears to increase in size during suturing, it is best to stop cleaning the wound and suture through the vitreous instead. The tissue incarceration must then be addressed from inside in a timely manner. The latter is especially important if the wound is posterior to the insertion of the extraocular muscles.

If a corneal wound reaches the limbus, the conjunctiva must always be opened so as to examine whether there is a scleral extension. Remember, again, the presence of one scleral wound does not imply that another one is not also present. If necessary, the conjunctiva must be opened 360 ° and the entire scleral surface inspected (suspecting an occult rupture, see above).

A huge distinction must be made between anterior (i.e., easily accessible) and posterior (more difficult or impossible to reach) wounds. The border is roughly at the equator – but the exact point of division is also determined by the size of the eyeball, the structure of the bony orbit, and swelling of the lid, etc.)

The recommended material for suturing is vicryl or silk. Never use running sutures in the sclera. As mentioned, the sutures may be full thickness, but be careful not to cause a choroidal bleeding. If necessary, use the two-step technique: let the needle emerge from under one wound edge before reinserting it onto the other side of the wound (pull the suture through one wound edge before re-engaging the sclera on the opposite side of the wound).

Anterior wounds:

The advantage of an anterior wound is that the conjunctiva can safely be opened so as to expose the entire length of the wound. The most optimal sequence of suture introduction can be decided based upon inspection; usually, the 50 % rule applies.

Posterior wounds:

A wound that starts anteriorly but then advances toward the posterior pole is much more dangerous than a purely anterior one for two reasons: it has a chance at the time of the injury of causing incarceration of tissue that threatens visual loss (retina), and the extrusion is more likely to be exacerbated due to the difficulty of closing the wound in an atraumatic manner. Below are a few suggestions that can help minimize the postinjury complications.

- Do not open the conjunctiva so as to expose the entire wound. Open it in a smaller area anteriorly and suture the sclera while carefully trimming any extruded vitreous. If uvea or retina prolapse is present, try to reposit them; the helping hand of an expert assistant is very useful, holding the tissue back with a blunt instrument such as a spatula. If reposition is impossible, light cauterization is preferred to tissue excision. This causes the tissue to shrink, allowing needle introduction (using the two-step method if necessary) without incorporating the choroid/retina in the suture loop.
- The wound is sutured progressively from the anterior edge toward the posterior pole ("close-as-you-go" technique).
- When the distal (posterior) end of the conjunctival dissection is reached with the scleral suturing, the conjunctiva is opened more posteriorly. Usually it is important at this point of the operation to ask the assistant to hold the orbital fat away/out from

the surgical field. It is best if initially the surgeon himself positions this instrument (e.g., orbital retractor) before handing it over to the assistant and verbally explains the importance of avoiding putting pressure on the eyeball. The retractor must be slightly repositioned by the assistant according to the maneuver the surgeon is actually doing: carefully moving it sideways, for example, when the surgeon wants to grab and pull through the needle.

- The eye may have to be held in a firm position. The assistant's other hand is used for this purpose; the best way to do this in the least traumatic way is to not cut the most proximal scleral suture but to use that suture as a tool.
- Dissecting an extraocular muscle for a wound that runs underneath it is almost never necessary. Rather, place a large traction suture under the muscle (using a muscle hook that has a hole toward its tip or by a needle that is advanced with its blunt end first) and then gently pull the muscle first in one then in the other direction. This usually allows adequate exposure to the wound without the risk of undue pressure on the globe.
- As the surgeon progressively advances toward the back of the eyeball, there will be a point where wound is so posterior that the difficulty of exposing the remaining wound or the unavoidable external pressure exerted on the globe when trying to expose the wound is just too great. Rather than risking a major additional tissue extrusion or even ECH, the surgeon should stop the wound closure and leave its posterior-most portion open. The wound heals very rapidly, and the risk of endophthalmitis is eliminated by the fact that the conjunctiva will be closed. In such cases it is even more important than usually to perform the vitrectomy early and address the tissue incarceration from the inside (see below).

One last issue to discuss is whether after the scleral wound has been closed it is advisable to perform prophylactic treatment: cryopexy and/or scleral buckling.

The answer to the first is easy: No. *Cryopexy*, even if not done blindly, increases the inflammation and thus the risk of PVR.

A prophylactic *scleral buckle* has the theoretical advantage of working against any internal con/traction, which in turns increases the risk of a retinal detachment. However, it is impossible to know in advance where the most ideal location of the buckle will be. The buckle also increases the intraoperative trauma and causes the postoperative scarring, and it usually inflicts on the patient inconvenience such as astigmatism and/or myopia. If the surgeon still prefers using a scleral buckle, rather than treat the traction at its source (i.e., an intraocular approach for the tissue incarceration), the best time to place the buckle is during the wound closure procedure, not during the secondary surgery.

4.6.2 Hyphema

In most cases the blood spontaneously clears from the anterior chamber, leaving no permanent sequelae. However, over half (53 % in the United States Eye Injury Registry, 61 % in the Hungarian Eye Injury Registry) of seriously injured eyes with a hyphema have posterior segment abnormalities severe enough to warrant vitrectomy; these posterior segment pathologies remain impossible to inspect unless the blood is removed early.

Another argument against delaying surgical evacuation of the intracameral blood is the risk of corneal blood staining (imbibition). Even a moderately elevated IOP can cause this if the hyphema is total and it persists for a few days. Furthermore, the risk of blood removal is extremely low if the procedure is properly done. There are several methods available for the surgeon; in addition to personal preference, the technique depends on whether the blood is clotted and the eye phakic.

- *Monomanual*: One paracentesis is created at the limbus (almost in the horizontal plane, thereby usually avoiding the need for a suture at the end of the procedure), typically at the most convenient location (temporally). The

slit created by the incision should be larger than the diameter of the irrigation cannula. The cannula is used to press down on the wound's lower lip so as to allow egress of the blood.

- *Semi-bimanual*: An anterior chamber maintainer is placed inferiorly; the second paracentesis is used for the entry of the irrigation cannula.
- *Bimanual*: the surgeon uses an irrigation and an aspiration cannula (as if a typical A/I is carried out during cataract surgery).
- *Clotted blood*: It is rarely possible to retract the blood with forceps or suction by a cannula/syringe. An anterior chamber maintainer should be placed and the vitrectomy probe used to engage, then cut and aspirate the clot. This is no easy maneuver, especially in a phakic eye; both the lens and the iris can be damaged (they are not visible until later in the procedure), and even the corneal endothelium can be traumatized. The probe's port must be in constant contact with the clot to avoid collapse of the anterior chamber and kept sideways to minimize the risk to adjacent structures.

4.6.3 Lens/IOL

This is a very complex issue; only a few important points are discussed here.

- Decide if the lens that is apparently injured is really so. It is easy to be fooled both ways (corneal edema, debris/fibrin in the anterior chamber, etc., can interfere with visualization; conversely, what appears as mild initial lens opacity may resolve in a few days). If in doubt, delay the lens removal.
- Decide whether the injured lens should be removed during the primary procedure (advantage: will not block view of the posterior segment) or secondarily.
- Try to determine whether the posterior capsule is injured. It is not always possible to establish this, but here are clues that help: these include the size of the corneal wound (the larger, the more likely), the injuring object, the presence of vitreous hemorrhage, or an IOFB. If roughly half of the cases of traumatic cataract, the posterior capsule is damaged – but only half of these could be observed preoperatively (datum from the Hungarian Eye Injury Registry).
- Decide the method of lens removal. If there is a risk of posterior capsular injury – or its presence cannot be excluded – it is safer to assume that it is present. It is much more difficult to recognize the vitreous prolapse, whether into the lens or the anterior chamber, intraoperatively than at the slit lamp. The injection of triamcinolone acetonide is the best diagnostic tool the surgeon can have (Fig. 4.9).

  Since the major risk is surgeon-induced traction on the anterior vitreous, transmitted to the vitreous base and leading to an iatrogenic retinal break, it is safer to use the vitrectomy cutter to remove the injured lens (lensectomy, as opposed to aspiration without cutting).

  If the nucleus is too hard for the vitrectomy probe, an anterior vitrectomy is performed first, after which the nucleus can be removed via fragmentation.

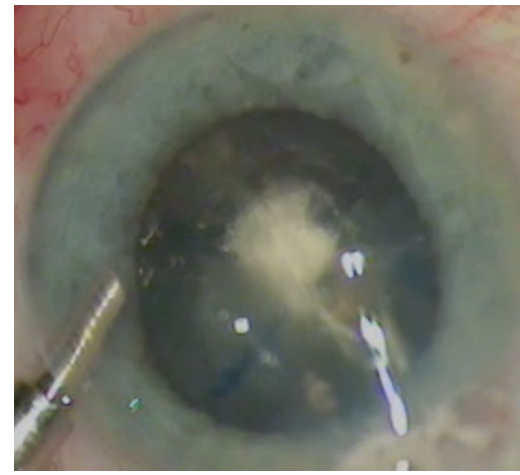

Fig. 4.9 Vitreous prolapse in the anterior chamber. The best method to visualize the presence of vitreous is to inject, then irrigate, triamcinolone acetonide. The crystals stick to the vitreous fibrils, allowing the surgeon not only to note that vitreous prolapse is present but also its extent. The triamcinolone also helps determine whether the vitreous has been completely removed

- The next question to decide is whether to remove the capsule/s. Many surgeons focus on keeping the capsule at all cost so that an IOL can be placed in or at least onto the bag, and they invent all kinds of surgical bravura to achieve this, including the use of a capsular tension ring in eyes with visible or suspected zonular defect.

  While the technical brilliance often seems to pay off intraoperatively, boosting the surgeon's self-confidence and encouraging him to repeatedly go down this path, the sad reality is that longer-term severe complications may arise – it is just that these are seen by a different person, leaving the original surgeon unaware (or untouched) by the consequences.

  The golden rule is that the outcome of the injury is not determined by whether the IOL is in the bag – but whether there is functioning retina (no PVR) or even an eyeball (no phthisis).

  The first author has been convinced by his experience that, especially in younger persons, it is much safer to remove the capsule completely and use a less conventional method of IOL implantation. The capsule can serve as a scaffold for proliferation – and anterior PVR is much more difficult to deal with than posterior PVR. Furthermore, even a capsule free of scar-producing cellular overgrowth can contract, eventually destroying the ciliary processes and lead to phthisis.

  True, this philosophy results in some capsules being removed unnecessarily; but this minor inconvenience is nothing compared to globe shrinkage that could have been prevented; and it is not possible to predict which eye would survive long-term.
- The IOL can be placed primarily or during a subsequent (or as the final) surgery. The advantages of both options are listed in Table 4.3. Again, it must be emphasized that in-the-bag IOL implantation is not the goal of the treatment process; it is a means to achieve in the most convenient way the necessary refractory compensation. How it is achieved should take the backseat compared to the more pressing issues.

Table 4.3 The advantages of primary vs. delayed IOL implantation is eyes with severe injury

Primary	Delayed
Single surgery	No or less difficulty selecting the ideal IOL power in the affected, rather than the fellow, eye
Reduced cost	Reduced inflammation during the primary surgery (no need to subsequently clean the lens surface of debris)
Increased convenience to patient	No issue finding the most appropriate surgical setting (logistics, infrastructure)
Fast visual rehabilitation – amblyopia prevention in young children	There may be no need for implantation at all (high myopia, lack of functioning retina, phthisical eye)
No risk of posterior synechia that would make late implantation difficult	Possible to identify (and order if necessary) the most appropriate type of IOL (e.g., an iris-lens prosthesis)

4.6.4 The Ciliary Body

As mentioned above, any vitreoretinal surgeon who does not address the issue of traction on the ciliary body, including cleaning the surface of the ciliary processes, and/or does not deal with a ciliary body detachment will pay a very high price later on – or, rather, the patient will pay the price.

The procedure of cleaning the processes is best done during the primary surgery. It is possible to achieve this even if there is severe anterior vitreous hemorrhage that is unsafe to remove (see below) since the surgeon works anterior to the vitreous base. As described earlier, the sclera is best indented by the surgeon himself as he removes all material covering the processes until they are all clearly visible. The two dangers of the procedure are hemorrhage (when working with a sharp instrument) and iatrogenic ciliary body detachment (when working with a blunt instrument). The former can be avoided by being cautious – and is the reason for the self-indentation, rather than having it done by an assistant.

The endoscope is a great tool to use for surgery on the ciliary body, although it has its own limitations, but its superb imagery allows the surgeon to cleanse the ciliary body completely [5].

A ciliary body detachment can readily be addressed by suturing it to the sclera. This can be done in two ways: directly, after opening the sclera over the detached area, or indirectly, using a double-armed long needle from some distance. It is up to the surgeon's individual decision which technique he chooses.

In some cases the detachment is small enough that a (usually expanding) gas bubble is sufficient to achieve permanent reattachment.

This author not uncommonly sees desperate patients with a late, inappropriately treated injury and some degree of hypotony (below 4 mmHg) or advanced phthisis. If the eye still has some function, it is worth even at this late stage to directly inspect at the ciliary body. In some fortunate cases the IOP can be restored as the ciliary body in these eyes is not destroyed. The ciliary processes are covered by fibrinous material or simply being pulled toward the visual axis by the contracting capsule. Especially in young patients, even if a large number of processes have disappeared, the remaining ones, once their surface is freed, may be sufficient to provide for globe survival.

In most eyes, however, the entire ciliary body is covered by a ring of white tissue. It is not possible to remove this scar tissue, and the eye is irreversibly dead.

4.6.5 Vitreous

There are three basic issues related to the vitreous: pus (see above); an IOFB (see below); and the most common one, hemorrhage.

The removal of a vitreous bleeding is a routine procedure; in a young patient affected by trauma, however, it may be very difficult to do. This is partly because the gel is healthy, and its mixture with the blood makes tissue identification much more uncertain (Fig. 4.10). The second reason is the firm attachment of the cortical hyaloid to the retina, even posteriorly and as late weeks after the injury (Fig. 4.4c). It must thus be emphasized again that spontaneous posterior vitreous detachment should not be expected in these eyes even in chronic cases. Failure to detach it, while making the surgeon's life easier intraoperatively, threatens with much worse postoperative consequences.

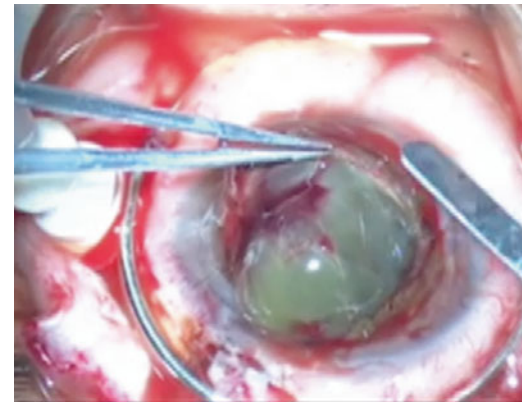

Fig. 4.10 Vitrectomy for severe vitreous hemorrhage. Open-sky maneuver during TKP vitrectomy. In this young patient, it is virtually impossible to distinguish between vitreous and retina just by appearance. Vertical digging, as opposed to horizontal shaving (see the text for more details) is the preferred technique, done in a closed environment

The first author uses the following technique to remove the vitreous-blood admixture.

- As a principle, ultrasonography is not requested preoperatively. First, because the findings are often misleading: they may suggest the presence of a retinal detachment when there is none or, worse, vice versa; second, because if it appears that there is no retinal detachment, the surgeon may be less inclined to proceed cautiously and remove large parts of the detached retina without recognizing it.
- The diagnostic dilemma continues intraoperatively and in two ways.

  One, bleeding or the lack of. What seems to be a fresh (presumably iatrogenic) hemorrhage may be no more than the release during vitrectomy of liquid, red blood previously trapped between layers of the vitreous. Conversely, the retina may be necrotic or ischemic, so no bleeding is caused by the vitrectomy probe biting into it.

  Two, distinguishing between retina and vitreous, as mentioned above. While in a nontraumatic scenario this is a rather straightforward decision, in these eyes the surgeon can be fooled, again in two ways. The layers of vitreous may contain streaks of blood, making the vitreous layer appear as the retina; or, conversely, the retina has occluded/nonperfused vessels, making the surgeon believe that he is removing vitreous.

- In a conventional approach, the surgeon proceeds with the vitrectomy in a horizontal fashion: carefully removing (shaving) layers of the vitreous by moving the vitrectomy probe in the horizontal plane.
- The first author has for many years advocated a very different approach: Proceeding in a vertical fashion, "digging" progressively deeper in a narrow channel (funnel) on the nasal side of the optic disc. The advantage of this technique is that it eventually becomes obvious what the location/position of the retina is. In most cases it is achieved before the retina is injured (iatrogenic retinectomy). In rare cases the retina does get bitten into, but this is instantly recognized as the subretinal space has an appearance vastly different from that of the preretinal space.

  Once the retina is identified, it is usually possible to separate retina and vitreous in a much larger area. The goal is to extend the separation as far to the periphery as possible.
- In the periphery the vitreous is trimmed as much as is compatible with safety. Scleral indentation is mandatory.
- There may be areas where the vitreoretinal adhesion is so strong that separation is not possible (young children) or would cause retinal damage (IOFB impact site). In such cases maximal trimming of the residual vitreous is carried out.

4.6.6 Retina

Direct retinal injury is surprisingly uncommon. If a retinal lesion such as a laceration or IOFB impact site is found, *prophylactic chorioretinectomy* [8] appears the most effective technique to deal with it.

- The procedure should be done before the retina is engulfed in the scar (causing PVR or the formation of full-thickness retinal folds), which is unavoidable if the injury involves the retinal pigment epithelium (RPE) or the sclera. The ideal timing for prophylactic chorioretinectomy is therefore during the primary repair or within the first 100 h postinjury.
- Make sure all vitreous has been removed in the vicinity of the retinal lesion, or at least trimmed if this is impossible (see above).
- Use the endodiathermy probe at the machine's highest power setting to create a barrier of continuous diathermy spots around the lesion. If a 20 g system is used, a single row is sufficient; with 23 or especially 25 g systems, two or three rows are recommended. The endodiathermy aims at evaporating tissue (signaled by the many small air bubbles that form during the procedure), not at preventing bleeding. The bubbles accumulating behind the lens/IOL may be so numerous that they interfere with visualization and require removal before the procedure is continued.
- Do not treat the lesion itself. If the retinal lesion is adjacent to a major blood vessel or the fovea, an individual decision must be made whether the unavoidable or likely consequences (vessel closure or foveal damage from the subsequently enlarging scar) versus the risk of PVR/retinal folding is greater.
- Vacuum the area so that the debris is removed.
- Silicone oil tamponade is recommended in most cases, although gas has also been found to work.
- In a few weeks the treated area should be a white zone (bare sclera), although occasionally harmless pigment deposits can be seen.
- Prophylactic chorioretinectomy can still be useful if done late [9] – but only for retinal folds, not if PVR has occurred. It must be mentioned that these folds may not appear too serious to the ophthalmologist, but they can be so annoying to the patient that he actually prefers covering the eye to prevent visual interference with the fellow eye.

Especially in eyes with contusion, a macular hole can develop rapidly. There is no consensus in the literature whether this should be treated early or hope for spontaneous closure. This is a great illustration why counseling, and accepting the patient's decision regarding these two options in this case, is so important.

To prevent retinal detachment, some surgeons place a scleral buckle (see above). Others will use a buckle or an encircling band if retinal detachment and PVR develop. Many surgeons, however,

address this problem from the inside alone (vitrectomy). PVR developing in an injured eye does not differ from that associated with retinal detachment (surgery); its treatment in the injured eye thus follows the rules typically prescribed for that in an eye with a retinal detachment. However, PVR may present earlier or be more aggressive in young patients, requiring earlier and perhaps matchingly aggressive intervention. Silicone oil should be used, not gas.

4.6.7 Intraocular Foreign Body

A few of the most important rules are summarized below.

- The goal is to treat the patient, the injured eye, not only to remove, and concentrate on, the IOFB. It is extremely rare that the complications arise from the IOFB itself; they are the consequences of the injury itself (mechanical damage to various intraocular tissues) or the reaction to it by the body and the surgeon. Metallosis (chemical injury) is the only longer-term complication due to the IOFB itself.
- Whether imaging (CT) is necessary for an IOFB that is otherwise visible depends on many factors: documentation for teaching or legal purposes, the possibility of more than one IOFB, the presence of an exit wound, etc.
- Early surgery (during the primary intervention) is usually recommended, although systemic antibiotic treatment may be sufficient to prevent endophthalmitis development [10]. However, this surgery is never restricted to IOFB removal: the eye must be treated according to the tissue pathologies present (and expected to develop).
- *IOFB in the anterior chamber*: As a general rule, do not use the original wound to extract the IOFB (exception: extra large IOFB with corneal damage so severe that transplantation is unavoidable anyway). Suture the entrance wound and prepare an extraction wound of proper size (see below) at a convenient location (usually temporally) but at least 90° away from where the IOFB is. Use viscoelastics only as much as absolutely needed (see above).
- *IOFB in the lens*: The lens may stay clear for a long time; [11]; therefore, do nothing if the IOFB is inert and the lens opacity does not interfere with vision (Fig. 4.11). If the IOFB is ferrous, however, it being intralenticular may not prevent siderosis. As seen above, an individual decision is needed, made jointly with the patient (counseling).
- *IOFB in the vitreous cavity*: The vitreous may be completely clear (uncommon) or have so much blood that the IOFB remains invisible until late during vitrectomy. Some surgeons complete the vitreous removal (including the still-attached posterior cortical vitreous, Fig. 4.12) and extract the IOFB then; others

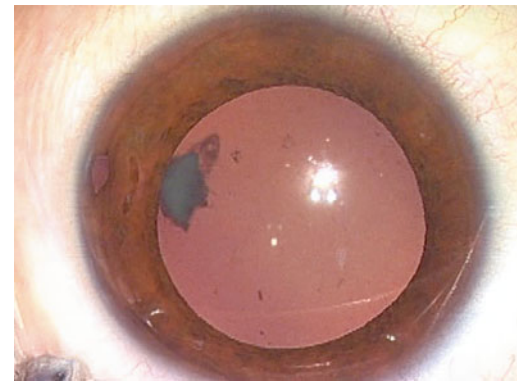

Fig. 4.11 Nonprogressive cataract after lens injury caused by an intraocular foreign body. The injury is 1 year old, yet no progression of the opacity has been detected

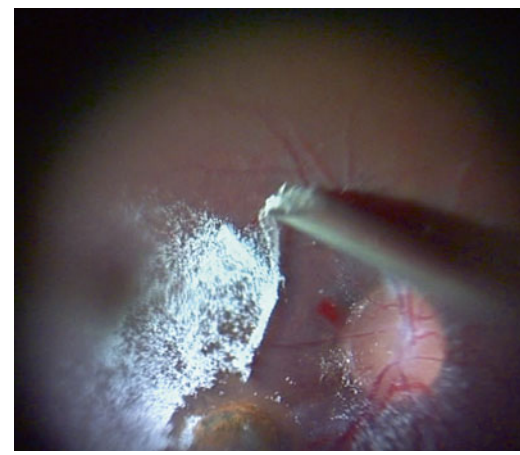

Fig. 4.12 Non-detached posterior hyaloid in a chronic injury. This injury is over 1 year old, yet the posterior vitreous face is still firmly attached, requiring the surgeon to mark it with triamcinolone acetonide to make sure it is completely removed

follow the opposite sequence. The logic behind the latter is that if the IOFB falls back during the extraction, the vitreous should cushion the macula. However, such loss of the IOFB during extraction should be prevented by keeping some basic rules in mind.

– The IOFB must be completely free, severed of all its connections to vitreous (and retina or fibrous capsule if the surgery has been delayed).
– The site of the extraction is typically the pars plana. If transconjunctival vitrectomy is performed, it is wise to open a new wound and simply suture that one after the extraction, and continue with the intraocular surgery using the original cannulas.
– Very large IOFBs may be extracted through a limbal wound, sacrificing the lens if necessary (although they rarely remain clear in such cases).
– The size of the extraction wound is not guesswork; it is this "trial-and-error" option that leads to loss of the IOFB during extraction. Its cross section, not its larger diameter, should be compared to the size of the vitrectomy probe, a measurement that is exactly known by the surgeon. The length of the wound should be a little larger than deemed necessary. It is not sufficient to open the sclera and choroid with a blade; the choroid must also be cut with Vannas scissors at both ends to avoid trapping/losing the IOFB during removal because the size of the wound in the (elastic) choroid is smaller than the size of the wound in the (inelastic) sclera (Fig. 4.13).

- *IOFB in the retina*: As mentioned before, the IOFB must be freed before removal is attempted. Sharp tools (blade, scissors) must be used to open any fibrous capsule (Fig. 4.14). If the IOFB is fresh but stuck in the deeper structures, endodiathermy is used to prevent bleeding. If the IOFB is lying on the retinal surface or is simply intraretinal, chorioretinectomy is not needed; with the involvement of the RPE, however, it is highly recommended (see above).
- *IOFB in the sclera*: If the object has not traversed the eye but simply got stuck upon entry,

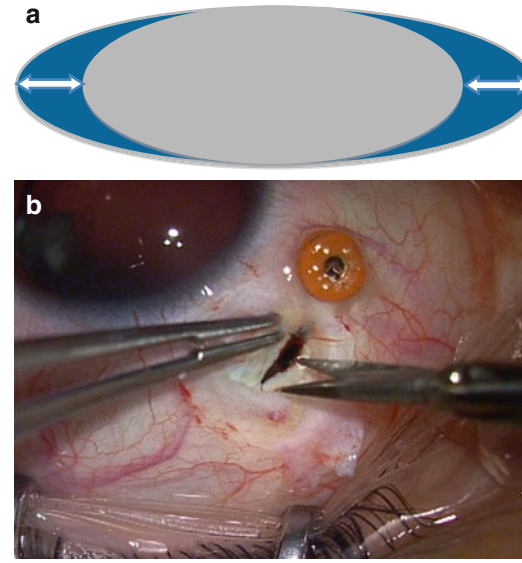

Fig. 4.13 Preparation of a scleral wound for intraocular foreign body extraction. (**a**) The sclera and choroid are penetrated with an MVR knife, but the choroid, being elastic (*gray area*) has now a wound length smaller than that of the inelastic sclera (*black area*). The choroid must be cut (*arrows*) at both ends with scissors. (**b**) The application of the principle in practice

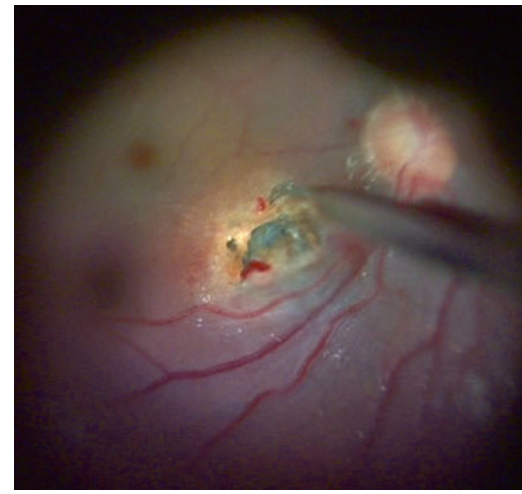

Fig. 4.14 Opening of the fibrous capsule of the intraocular foreign body. This patient with a chronic IOFB has decided, after extensive counseling, that the risk of siderosis was too great – even though the visual acuity is still full. The IOFB is lodged in the sclera, close to the superotemporal vessels in the maculopapular bundle. The distal blade of a 23 g scissors is used to open the capsule before an intraocular magnet is used to extract the object

it is typically located anteriorly and can be retrieved via a simple cut-down (only external surgery). If it is posterior (following an intraocular path), it may be best to leave it in situ and perform regular ERGs to detect siderosis early. Should siderosis develop and surgery be necessary, it is a difficult one since the globe certainly will have an open exit wound intraoperatively, with consequent loss of the irrigation fluid into the orbit. The foreign body is typically very hard to free; it may be preferred to dislodge it into the orbit that try to bring it intraocularly and then extract it.

4.6.8 Vitreoretinal Surgery: A Few Technical Issues

Of the many, space limitation permits the discussion of only a few selected issues.

- *Gauge*. "Which one is preferred?" This question is often asked, but it is really not an important one. The surgeon should select the one he is most comfortable with and use that as the "standard," deviating from it only when the need arises. For instance, 23 g is fine for most maneuvers; others can be done with some compromise (e.g., the fibrous capsule around an IOFB opened with scissors rather than a microvitreal blade, Fig. 4.14). Still others cannot be achieved with the transconjunctival approach and require the opening of another wound or removing the 23 g cannula and enlarging it to 20 g or whatever size is required (Fig. 4.13b).
- *Bimanual surgery*. In general, having two working hands has definite advantages over a monomanual approach. However, most vitreoretinal surgeons are comfortable with, and able, executing most maneuvers, achieving most goals, using only one hand. If the need arises, the surgeon should introduce a chandelier light or some other non-hand-held light source – but it is not necessary to routinely do so, even in the most complicated cases.
- *Endoscope use*. This is an extremely useful tool [5] for certain indications and in the expert's hands. The difficulties, challenges, and downsides, however, must not be neglected when employing this technique.

In summary, this chapter did not intend to teach surgeons every trick in the book so as to successfully treat every patient with a serious eye injury. Such teaching is impossible, even in a book of infinite length, much less in a single chapter. Furthermore, learning (by reading) all what is needed for success is impossible: there is no recipe to prescribe. Every case is different and all require some individualized approach.

This chapter thus intended to show the technique of certain surgical maneuvers, but, more importantly, to convey a thought process, a logic, the fundamental elements of how a patient's eye injury should be approached, and how the surgeon should consider designing the management plan. Furthermore, the learning of such skills is a never-ending process; these authors, with a combined seven decades of doing it, are still developing new ideas, changing their own practice, to improve on the previous experience.

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Management of Proliferative Vitreoretinopathy

5

J. García-Arumi and D. Velázquez-Villoria

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J. García-Arumi (✉)
Chairman and Professor Universidad Autónoma de Barcelona, Instituto de Microcirugía Ocular, Hospital Universitario Valle Hebrón, Barcelona, Spain
e-mail: jgarcia.arumi@gmail.com

D. Velázquez-Villoria
Istituto de Microcirugia Ocular, Hospital Universitario Valle Hebrón, Barcelona, Spain

5.1 Introduction

Proliferative vitreoretinopathy (PVR) is the clinical syndrome associated with retinal traction and detachment in which cells with proliferative potential multiply and contract on retinal surfaces and in the vitreous compartment. PVR presents with a broad spectrum of severity ranging from subtle retinal wrinkling to a total rigid retinal detachment, retinal shortening, and advanced periretinal proliferation. Although surgical reattachment of retinas associated with PVR can now be achieved in most cases, visual results remain disappointing. Therefore, prevention through early recognition of risk factors and subtle signs of PVR and appropriate modification of standard surgical techniques for retinal detachment remain of great importance.

5.2 Pathophysiology

PVR is the proliferation of cells derived from retinal pigment epithelium (RPE), glia, or inflam-

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matory recruitment on the retinal surfaces and within the vitreous gel [1, 2]. These metaplastic cells transdifferentiate and assume contractile properties through internal cellular contractile proteins and by laying down extracellular collagen [3] forming a tissue layer with contractile properties. This contractile tissue exerts traction directly on the retina or through the vitreous gel, leading to retinal breaks and retinal traction.

These cells proliferate through available scaffolding, either the retinal surfaces or elements of residual vitreous gel. The vitreous compartment is normally almost devoid of cellular content with just a few hyalocytes [4]. It is protected from outside invasion by the internal limiting membrane of the retina and from cytokines and other chemoattractants by the blood–retinal barrier. The process of PVR can start when there is an interruption to the surface lining such as what occurs in a posterior vitreous detachment or retinal tears. Retinal tears with surrounding detachment may encourage inflow of freed-up RPE cells through the break into the vitreous cavity and onto the retinal surface or onto residual contracted vitreous strands at the vitreous base. Multiple causes for the breakdown of the blood–retinal barrier can lead to the influx of circulating inflammatory cells and proteins into the vitreous cavity, such as cryotherapy, intraocular inflammation, or trauma [5]. The PVR process is self-propagating and can be considered an inappropriate excess wound healing response. Cellular proliferation and contraction increases the breakdown of the blood–ocular barrier, in turn causing more traction and more influx of inflammatory cytokines and cells. Macular pucker after retinal detachment (RD) repair can be considered a mild form of PVR. Proliferative membranes more frequently develop in the inferior quadrants, probably because RPE cells and inflammatory cells settle inferiorly with gravity.

The PVR process usually takes 4–12 weeks to develop a critical mass of cells with contractile properties after RD surgery. The proliferating cells go through a life circle: as they progressively lay down collagen, the membranes become hypocellular leaving contracted collagen sheets, membranes, and cords in the vitreous cavity, on the retinal surface, and sometimes under the retina [4].

5.3 Risk Factors for Development of PVR

PVR usually develops 4–12 weeks after previous retinal detachment repair, whether by scleral buckling, primary vitrectomy, or both.

Only a few eyes develop PVR spontaneously with RD prior to surgery (5,1–11,6 % of cases) [6]. The risks in the presence of RD are increased with large retinal breaks or retinal tears, vitreous hemorrhage, trauma, inflammation of the posterior segment, or chorioretinitis [7, 8].

Surgical problems that increase the risk of PVR include vitreous and subretinal bleeding, choroidal detachment, failure to close retinal breaks resulting in prolonged retinal detachment, incarceration of retina, and heavy or excessive cryotherapy [2, 9].

5.4 Classification of PVR

The most commonly used classification system remains that published by the Retina Society Terminology Committee in 1983 [10]. Table 5.1

Table 5.1 Retina society PVR classification (1983)

Grade (stage)	Characteristics
A	Vitreous haze, vitreous pigment clumps
B	Wrinkling of the inner retinal surface, rolled edge of retinal break, retinal stiffness, vessel tortuosity
C	Full-thickness retinal folds in
C1	One quadrant
C2	Two quadrants
C3	Three quadrants
D	Fixed retinal folds in four quadrants
D1	Wide funnel shape
D2	Narrow funnel shape
D3	Closed funnel (optic nerve not visible)

Reprinted from Retina Society Terminology Committee [10]

The revised classification of PVR of 1991 [11] took into account more detailed information about the location, extent, and severity of PVR in an individual eye and hence is more useful especially for clinical trials (Tables 5.2 and 5.3).

5.5 Surgical Management

There has been substantial improvement in the success rate of surgery for PVR progressively over the past four decades [12]. The clinical severity of PVR is very variable, and therefore the extent and timing for surgery should be planned accordingly. In cases with the macula attached or salvageable, it is desired to perform prompt surgery. Leaving an eye with a retinal detachment and early PVR almost always will lead to further progression, so most eyes deemed to be operable should be operated on as soon as possible. On the other hand, PVR is less likely to recur if surgery is delayed until epiretinal proliferation is mature, and it may be better to wait a few days and quiet the eye down with corticosteroids if the macular vision is not salvageable until the inflammatory activity is less intense [4].

The objectives of vitreoretinal surgery for PVR are to release any residual retinal traction and to close any open retinal breaks. These goals may be achieved by an encircling scleral buckle, meticulous relief of all retinal traction with vitrectomy, and temporary or long-term tamponade of the retina with long-acting gas or silicone oil.

Table 5.2 Updated proliferative vitreoretinopathy: grade classification (1991)

Grade (stage)	Characteristics
A	Vitreous haze, vitreous pigment clumps, pigment clusters on inferior retina
B	Wrinkling of the inner retinal surface, retinal stiffness, vessel tortuosity, rolled and irregular edge of retinal break, decreased mobility of vitreous
CP 1-12	Posterior to equator, focal, diffuse, or circumferential full-thickness folds, subretinal strands[a]
CA 1-12	Anterior to equator, focal, diffuse, or circumferential full-thickness folds, subretinal strands, anterior displacement, condensed vitreous strands[a]

[a]Expressed in the total lumber of clock hours involved

5.5.1 Circumferential Buckling and PVR

Although vitrectomy has become the main procedure for PVR, a 360° scleral buckle remains a fundamental requirement for most eyes with established PVR.

In PVR cases, the inferior part of the vitreous base becomes fibrocellular and continues to contract even after a former vitrectomy [4]. Since it is virtually impossible to remove the whole vitreous base, placing a high encircling scleral buckle will provide support to the vitreous base against further traction. It relives peripheral anteroposterior retinal traction, closing the peripheral retinal breaks by stretching the peripheral retina over the

Table 5.3 Updated proliferative vitreoretinopathy: contraction type classification (1991)

Type	Location	Features
Focal	Posterior	Starfold posterior to vitreous base
Diffuse	Posterior	Confluent starfolds posterior to vitreous base; optic disk may not be visible
Subretinal	Anterior/posterior	Proliferation under the retina; annular strand near disk; linear strands; moth-eaten-appearing sheets
Circumferential	Anterior	Contraction along posterior edge of vitreous base with central displacement of the retina; peripheral retina stretched; posterior retina in radial folds
Anterior	Anterior	Vitreous base pulled anteriorly by proliferative tissue; peripheral retinal trough; displacement ciliary processes may be stretched and may be covered by membrane; iris may be retracted

Reprinted from Machemer et al. [11]

convex buckle. Furthermore, it will relieve circumferential retinal traction by reducing the circumference of the equatorial and anterior sclera. By these two mechanisms, it will change the vector force of contraction, so the retina is no longer pulled away from the retinal pigment epithelium.

Placing a high encircling scleral buckle will help to isolate the peripheral retina from the posterior retina, forming a new, more posterior "ora serrata" on the crest of the buckle. This allows the posterior retina to remain attached in some eyes in which there is peripheral retinal detachment because of peripheral epiretinal proliferation.

Eyes with localized or relatively inactive PVR may be successfully reattached with an encircling scleral buckle, drainage of subretinal fluid, and peripheral laser photocoagulation alone. Most cases, however, require a vitrectomy and internal tamponade with silicone oil or long-acting gas.

5.5.2 Vitrectomy and PVR

Some authors rely on a meticulous vitrectomy and silicone oil tamponade without scleral buckling and report comparable results with a combined procedure [13], although in our experience, we prefer combining vitrectomy and scleral buckling in PVR cases. Almost all eyes with retinal detachment and PVR also require a vitrectomy to remove all vitreous gel. It is necessary to relieve all traction by division and peeling or delamination of fixed membranes causing anterior traction and to release the tractional effect on scarred shortened retina.

Vitreous can be very adherent in the vitreous base, making it difficult to shave it all and eliminate all epiretinal proliferation. These surgical steps are greatly facilitated by the advances in technology now available. Wide-angle viewing systems are either indirect and attached to the operating microscope or consist of an operating corneal contact lens. Contact lenses provide a crisper image and easier visual access to the far inferior periphery but require frequent repositioning. Indirect viewing systems provide a less panoramic view and depend on precise eye positioning, making angulation more difficult [4]. Wide-field illumination is achieved with a range of fiber-optic light sources or a chandelier arrangement inserted into the eye through a separate pars plana entry site. Vitreous cutting probes have vastly improved, and the surgeon has the choice of smaller gauge instruments (23G, 25G) and the traditional 20G instruments. Modern vitreous probes can cycle at up to 7,500 cycles per minute and have a variable duty cycle. Shaving mode vitrectomy combines a minimum port open time (shaving mode) with a high-speed vitreous cutting (5,000–7,500 cpm) and a low vacuum (80–100 mmHg) and thus allows the instrument to be held closer to the retina.

Another major advance has been the intraoperative use of perfluorocarbon liquid (PFCL) which displaces subretinal fluid anteriorly and flattens the bullous posterior retina. This helps exposing and stabilizing the peripheral retina during dissection and demonstrates residual proliferation.

Anterior displacement from anteroposterior contraction of the vitreous base can be relieved by scissors cutting circumferentially. Anterior membranes should be eliminated. Membranes may be elevated with a vitreoretinal pick, grasped with forceps, and peeled from the retinal surface. In complex cases, bimanual dissection techniques are required, using forceps, scissors, or the vitreous probe.

In some eyes, peripheral vitreous base proliferations cannot be separated from the retina, and retinotomies or retinectomies must be considered when residual traction persists.

Immature membranes are difficult to identify and have a tendency to fragment, leaving residual cells that can reproliferate.

Internal drainage of subretinal fluid and fluid–air exchange of the vitreous compartment allow the testing of release of all retinal traction. Any persistent retinal elevation after fluid-air exchange indicates that complete release of traction has not been achieved.

Reattached retina and open retinal breaks are sealed with endolaser photocoagulation or

cryotherapy. We usually prefer endolaser photocoagulation, as it induces less intraocular inflammation and associates a lower risk of hemorrhagic choroidal detachment. Intraocular tamponades in PVR cases include perfluoropropane (C3F8) gas and silicone oil (SO). Although a controlled trial showed the eventual outcomes to be similar, many surgeons prefer SO to gas because it results in less postoperative inflammation, quicker rehabilitation, and fewer reoperations [4].

The use of heavier-than-water SO, such as Densiron, can also improve inferior retinal tamponade in severe cases of PVR and is being increasingly used. Densiron has a specific gravity of 1.06 (higher than water) and is specially indicated in cases of RRD with inferior breaks. When injected in cases of retinal detachments with inferior retinal breaks, it displaces any aqueous (containing proliferative cytokines and activated cells) to the superior retina, where there are no retinal breaks. The Heavy Silicone Oil Study compared the effect of Densiron and conventional SO, in eyes with inferior and posterior PVR grade C or above [14]. No significant difference between both groups was observed regarding anatomical success or visual outcomes. No significant adverse effects were observed during the course of the study, including emulsification of SO [14].

5.5.3 Management of the Lens in PVR

Lensectomy should be performed if the cataract is sufficiently dense to prevent an accurate visualization of the retina or in cases in which an anterior dissection of the vitreous base is needed.

The posterior capsule and the lens are eliminated with the vitreotome, using a low cut-rate and a high aspiration. Moreover, we usually polish the anterior capsule with the vitreotome using a low aspiration, in order to eliminate the remaining epithelial cells and prevent the anterior capsule opacification.

We should take into account several considerations when using SO as an internal tamponade. The lens always becomes cataractous with SO, and it can be replaced at the time of SO removal or when it becomes visually significant.

The anterior capsule should be preserved, as it provides support for future IOL implantation and compartmentalization of spaces. If the capsule is totally removed, there is risk from SO contact to the corneal endothelium in the longer term. An inferior iridotomy will reduce this risk [15].

If the patient is left aphakic but the anterior capsule is preserved, then it always becomes opaque in the presence of SO, and subsequent YAG laser capsulotomy is carried out at the time of insertion of an intraocular lens in the sulcus 2–3 months later [4].

Intraocular lens can be placed inside the capsular bag or in the sulcus in mild PVR cases. However, an IOL will provide worse anterior retinal viewing, so insertion of IOL should be avoided in anterior PVR cases.

In younger patients with a softer lens, it is possible to remove the contents and still preserve both anterior and posterior capsules. In this case, an intraocular lens is inserted after vitrectomy but before fluid–gas exchange into the bag.

5.5.4 Core Vitrectomy and Removal of the Vitreous Base

Vitreous cutting probes have vastly improved, and the three available probe sizes (20G, 23G, 25G) are all acceptable.

The 25G cutting probe is the slowest of the three sizes, although it has the smallest opening and it can be hold closer to the retina. It is more flexible, so it can be difficult to rotate the eye superiorly enough to comfortably remove vitreous off a superior retinal break with a mobile detached retina.

The 20G probe has the largest opening and most efficient fluidics, but the sclerotomies need suturing. We believe 23G is the best choice, because it is rigid enough in order to manipulate the eye while performing a peripheral vitrectomy, has similar fluidics to the 20G, and does not require suturing the sclerotomies in most cases.

Most eyes with established PVR already have a posterior vitreous detachment. Any remaining central gel should be removed completely, and then the peripheral vitreous is removed meticulously and as completely as possible, particularly inferiorly where pigment and inflammatory cells tend to gravitate. This process is facilitated by the modern, high-speed vitrectomy cutters with the port close to the tip. With these cutters, it is possible to shave the attached vitreous off the retinal surface without engaging the retina.

Modern vitrectomy cutters also offer the possibility of selecting the best parameters for each step of the surgery: core mode and shaving mode.

Shaving mode combines a high cut-rate and a low aspiration and enables us to remove the vitreous base while holding the vitrectomy port very close to the retina. Core mode combines a high aspiration and a lower cut-rate and enables us to eliminate the central vitreous very efficiently.

Removal of the inferior vitreous base is best facilitated by scleral indentation. Formed vitreous attached to the peripheral retina is also very difficult to remove if the retina is detached and mobile, and in which case it can be stabilized at this stage by partly filling the vitreous compartment with PFCL. This has the effect of stabilizing the retina by displacing the subretinal fluid anteriorly. In cases where vitreous remains attached to the retinal surface posteriorly as well as at the vitreous base, the process of removal may be facilitated by an intravitreal injection of triamcinolone. The white suspension sticks to vitreous membranes and residual vitreous gel, making them both more visible [16, 17].

5.5.5 Removal of Epiretinal Membranes and Use of Perfluorocarbon Heavy Fluid

After a meticulous vitrectomy any fixed folds or retinal contraction due to epiretinal membranes must be dealt with.

Epiretinal membranes are often poorly visible because of their transparency. Identifying these membranes becomes easier with vital dyes. Trypan blue is a dye with high affinity to tissues with high rates of cellular proliferation like ERM and stains the nuclei of damaged and dead cells, as well as the extracellular matrix. This provides better visibility and delineation of ERM during PVR surgery, enabling a more complete ERM removal and thus a higher rate of long-term reattachment [18, 19]. Membranes are peeled from the retinal surface from the posterior pole outwards. If an edge is found, it can be peeled preferably with vitreous forceps. If not, a retinal pick may help find a plane and elevate the membrane. Care must be taken to avoid creating iatrogenic retinal breaks. Special attention is given to any fixed folds where contracted membrane tends to fold the retina over underlying valleys. Any membrane involving the macula must be peeled. Some surgeons advocate the injection of vital dye such as *brilliant blue* at this point to stain and allow peeling of the contracted internal limiting membrane, particularly if the retinal surface at the posterior pole is still stiff. The degree of adherence of epiretinal membranes to the retinal surface varies so that some may be peeled easily in a single sheet, while many others have to be freed up in multiple pieces or delaminated. Peeling of surface retinal membranes and internal limiting membrane is much easier over attached retina. In many cases, drainage of subretinal fluid through an open retinal break or flattening the posterior retina by the injection of perfluorocarbon liquid facilitates this process.

PFCL is extremely useful in posterior PVR cases: it opens the funnel, exposing any epiretinal or subretinal membranes. PFCL stabilizes the retina during membrane peeling, acting as a second hand holding the retina in place. As areas of posterior traction are removed, PFCL is added to flatten and stabilize the peripheral retina.

Care must always be taken to avoid the risk of heavy fluid passing through a retinal break under the retina. This can occur if tractional membranes are still elevating a retinal tear. The heavy liquid fill is stopped short of any such retinal break until it is dissected, mobilized, and flattened.

5.5.6 Removal of Anterior Tractional Membranes

Fibroblastic organization of the vitreous base can cause elevation and traction of the peripheral retina. This must be sectioned to fully mobilize the retina and allow retinal reattachment. Vitrectomy should be as extensive anteriorly as possible to decrease the risk of recurrence of PVR. High-speed small-size vitreous cutters (23G or 25G) have the opening closer to the end of the probe, so they can be hold closer to the retina, facilitating the shaving of the vitreous base. Vertical action scissors are often no longer needed.

In complex cases, bimanual dissection techniques are required, using forceps, scissors, or the vitreous probe. External scleral depression and wide-angle viewing systems are extremely helpful for removing anterior tractional membranes.

In order to obtain a better visualization of the anterior membranes, we prefer to inject a PFCL bubble in the posterior pole up to the level of the membranes and then perform the staining with trypan blue.

If extensive anterior traction is noted preoperatively, then planned lens extraction can also facilitate the dissection, but with modern instrumentation and viewing systems, this option remains necessary only in very complex cases.

5.5.7 Removal of Subretinal Membranes

Subretinal membranes (SRM) may appear in up to 3% of rhegmatogenous retinal detachments. Subretinal membranes are considered a form of PVR and thus appear usually associated to epiretinal proliferation. Histopathologic studies demonstrate hypocellular membranes, with a collagen matrix and some melanic pigmentation in plaques. In previous studies the glial cells were considered to be the origin of SRM, although more recent studies identify the RPE cells as the source of these membranes [20]. In the majority of cases, they are identified intraoperatively but do not prevent retinal reattachment.

Subretinal membranes should only be removed in cases in which they prevent retinal reattachment, as there is risk of damaging the outer retina in this procedure.

Subretinal membranes are usually associated with a worse visual prognosis, achieving BCVA ≥5/200 in 20 % of cases [21].

Subretinal membranes may present with different morphology. The most common configuration is single or branching brands of subretinal tissue. In some cases they may proliferate on the subretinal space conforming sheets of subretinal tissue, which are more difficult to remove without causing damage to the outer retinal layers. Other cases present with an annular peripapillary configuration that almost always prevents retinal reattachment or posterior epiretinal membrane dissection.

Annular configuration membranes should always be removed. In the rest of cases, we should test retinal reattachment intraoperatively before removing the SRM. Firstly, a complete epiretinal membrane removal should be achieved, including those extending in the anterior retina. After performing a 360° scleral indentation, we should test retinal reattachment with PFCL or air and only decide to remove SRM if residual traction persists.

Surgical removal technique for SRM

(A) *Single or branching band*: create a small retinotomy overlying SRM parallel to the nerve fiber layer in the superior quadrants, as far as possible from the macular area. Using a bimanual technique and a chandelier light, grasp the membrane through the retinotomy with vitreous forceps, and pull it through the retinotomy into the vitreous compartment (Fig. 5.1).

(B) *Annular configuration producing a narrow funnel*: create a peripheral 120° retinotomy, grasp SRM with forceps, and using a bimanual technique segment the membrane with scissors. Another option could be performing a superior nasal retinotomy and grasping firmly the SRM with forceps and pulling it out directly onto the vitreous cavity (Fig. 5.2a, b).

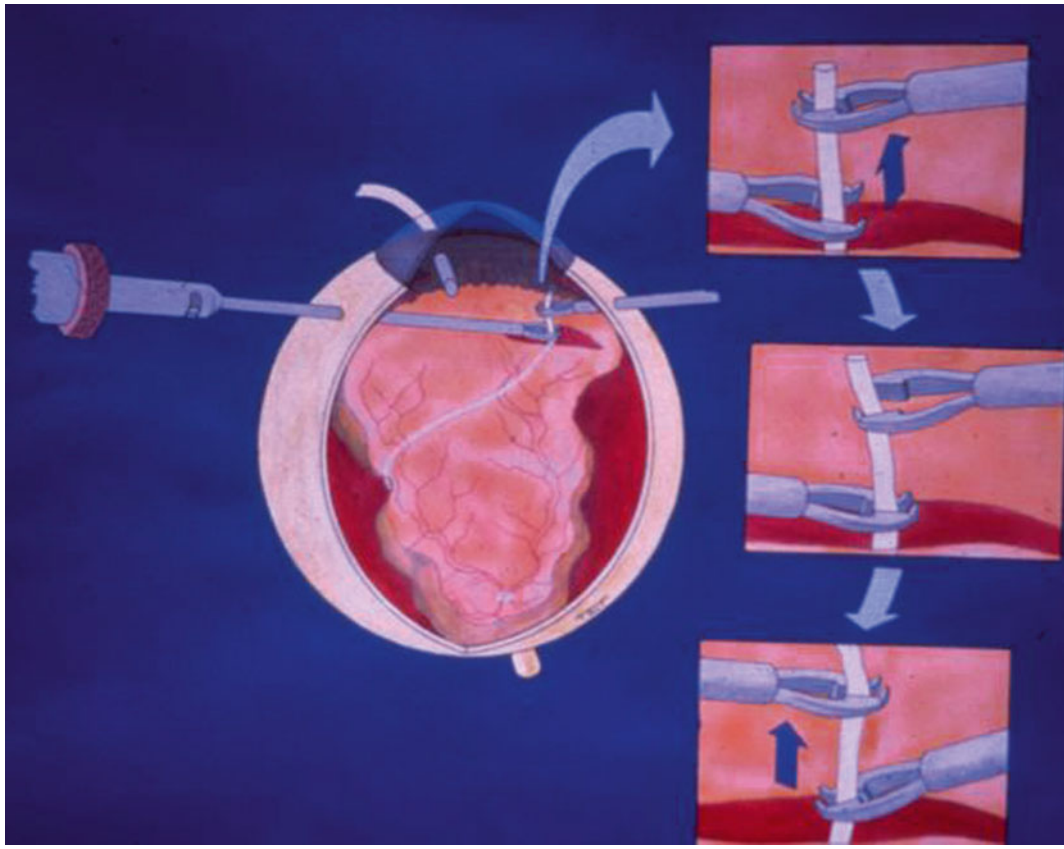


Fig. 5.1 Surgical removal of subretinal membranes (SRM): single or branching band. Perform a retinotomy overlying SRM parallel to the nerve fiber layer in the superior quadrants. Using a bimanual technique, dissect the SRM with two forceps or forceps and scissors

5.5.8 Fluid–Air Exchange

In order to reattach the mobilized retina after vitrectomy and membrane dissection, the subretinal fluid is drained through the retinal breaks.

Heavy perfluorocarbon liquid is injected into the vitreous cavity to displace the remaining subretinal fluid anteriorly where it is aspirated through a preexisting retinal break. A silicone-tipped extrusion cannula and positive suction facilitate this process while maintaining a constant intraocular pressure with continuous air infusion. Planned retinotomies for draining the remaining subretinal fluid should be avoided, as they may lead to focal proliferative vitreoretinopathy associated with the retinotomy site or subretinal neovascularization in some cases [22].

5.5.9 Testing Adequacy of Relief of Traction and Relaxing Retinotomy

After dissecting the epiretinal membranes and the anterior tractional membranes at the vitreous base, the adequacy of retinal mobilization can be tested by a complete fluid–air exchange. An extrusion needle is placed through the sclerotomy site, and all vitreous fluid and any residual subretinal fluid are aspirated by positive suction. Drainage of subretinal fluid is facilitated by a silicone soft tubing extension on the needle. If residual traction is present or the retina shortened by surface or intraretinal gliosis, it fails to flatten completely. This test informs the surgeon that adequate mobilization of the retina has not been achieved. It can be due to subretinal membranes

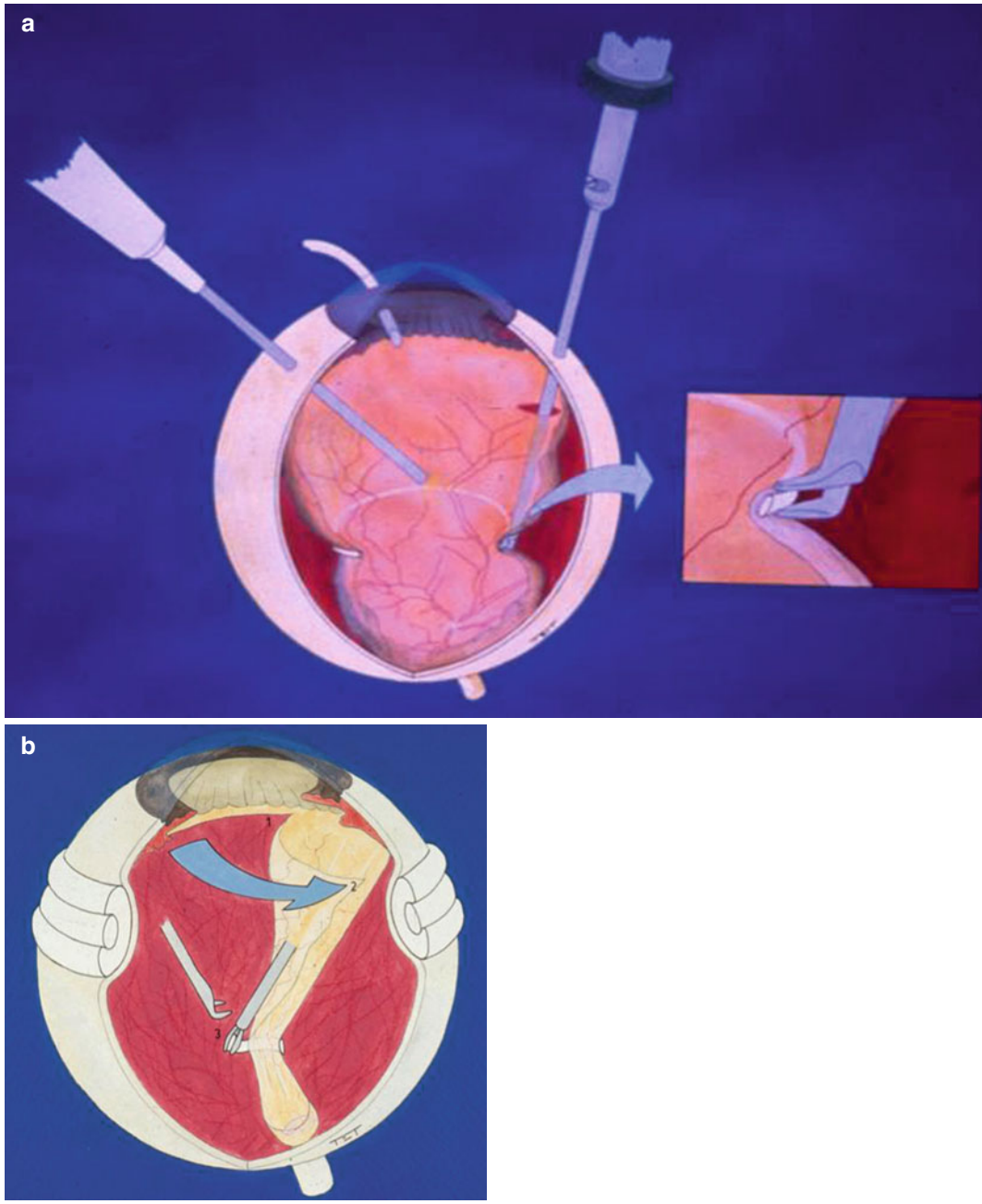
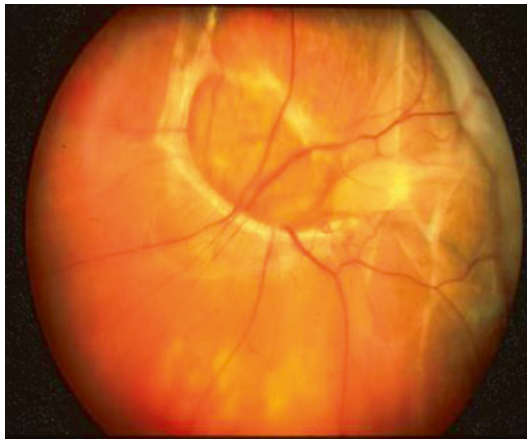


Fig. 5.2 (**a**) Surgical removal of subretinal membranes (SRM): annular configuration. Option 1: Perform a superior nasal retinotomy and dissect SRM with forceps. (**b**) Surgical removal of subretinal membranes (SRM): annular configuration. Option 2: Perform a 120° peripheral retinotomy and bimanual dissection of SRM with forceps and scissors

or intrinsic retinal contraction. If retinal contraction remains after complete membrane removal, we should consider to perform a relaxing retinectomy [23].

As a general surgical principle, peripheral retinotomies are less functionally significant than posterior retinotomies, and so circumferential relaxing retinotomies are preferred to radial retinotomies.



Case 1a Subretinal membrane in annular configuration producing a narrow funnel and preventing retinal reattachment

Case 1b Same patient after dissecting the subretinal membrane through a superior nasal retinotomy. Complete retinal reattachment

Surgical steps of relaxing retinotomies (Fig. 5.3):

(a) Evaluate the extent of the retinectomy: using a wide-field viewing system, scleral depression and PFCL will help to determine the retinal section demonstrating residual traction.
(b) Diathermy in blood vessels at the limit of the posterior area with residual traction: it will help control intraoperative bleeding.
(c) The affected retina can be cut with vitreous scissors or, more conveniently, with the vitreous probe.
(d) Once all residual traction is released, we should inject more PFCL into the vitreous cavity, so that PFCL level is brought anterior to the level of the retinotomy in order to reattach the remaining retina.
(e) Endophotocoagulation of the edge of the retina. We prefer to perform this step under PFCL and scleral indentation.
(f) PFCL–air or PFCL–silicone oil exchange. First remove the subretinal fluid anterior to the PFCL in order to achieve a "dry" anterior edge of the retina. A direct PFCL–silicone oil exchange is preferable in large retinectomies using a dual technique.

Surgical tips for relaxing retinotomies:

- PFCL stabilizes the retina during retinectomy, acting as a second hand holding the retina in place.
- Be aware of the potential risk of choroidal damage while performing the retinotomy with the scissors or vitreous probe.
- The anterior flap of the retinotomy is avascular and nonfunctional. We should remove the retina anterior to a large retinotomy.
- Retinotomy can be extended anteriorly in some cases into the uninvolved retina to maximize relaxation.
- After a large circumferential retinotomy, the posterior free edge may contract under SO almost back to the disk and macula and compromise the visual outcome. A radial retinotomy may sometimes relieve residual traction and avoid this posterior retraction of the cut retinal edge.
- Hypotony is a possible complication. It is due to an anterior retinal flap covering the ciliary body. All anterior tractional membranes affecting the ciliary body should be released.

Failure to relieve all traction prevents the retina from apposing the pigment epithelial surface, resulting in a poor anatomical result.

Despite achieving retinal reattachment, visual prognosis is usually poor in these cases. Retinal reattachment rate is 70–80 % in most series [24, 25], while visual acuity ≥20/200 is only achieved in 50 % of cases [26, 27].

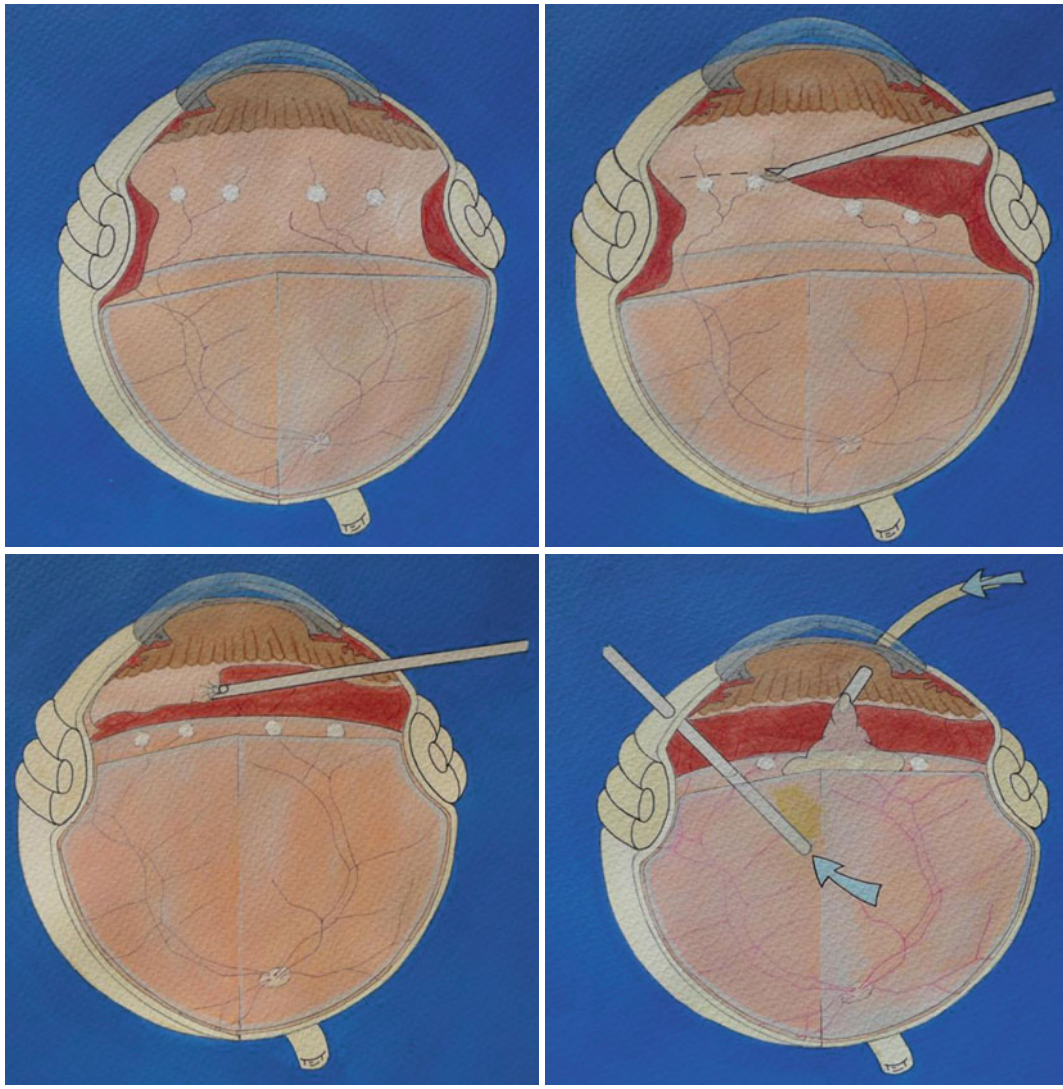


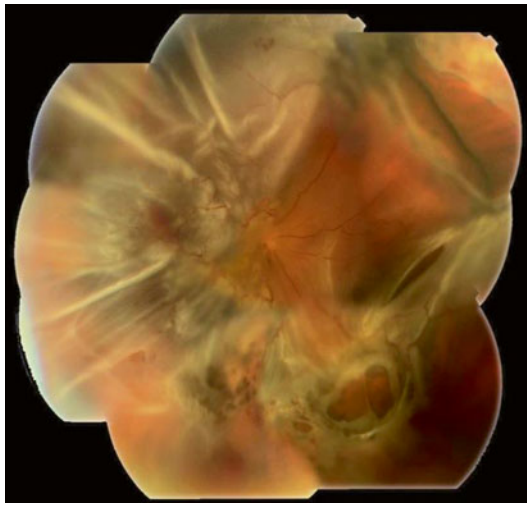
Fig. 5.3 Surgical steps for relaxing retinotomies: relaxing retinotomies are only indicated in cases of intrinsic retinal contraction preventing retinal reattachment, after suturing a circumferential buckle and dissecting epiretinal and subretinal membranes

5.5.10 Creating Chorioretinal Adhesion

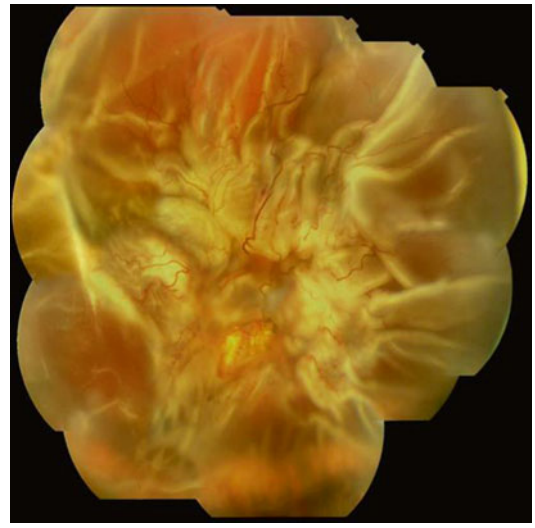
Following retinal reattachment, all retinal breaks are surrounded with visible retinal burns. If an extensive retinectomy has been necessary, we should perform up to three rows of endolaser in the affected area applied as multiple discontinuous spots, in order to create a firm chorioretinal adhesion. Laser photocoagulation is preferable to cryotherapy as it causes less postoperative inflammation, cellular proliferation, and recurrence of PVR [4]. If visible laser burns cannot be achieved by endolaser, it usually means that a shallow subretinal fluid persists in that area, and in these cases cryotherapy is still needed.

5.5.11 Intraocular Tamponade

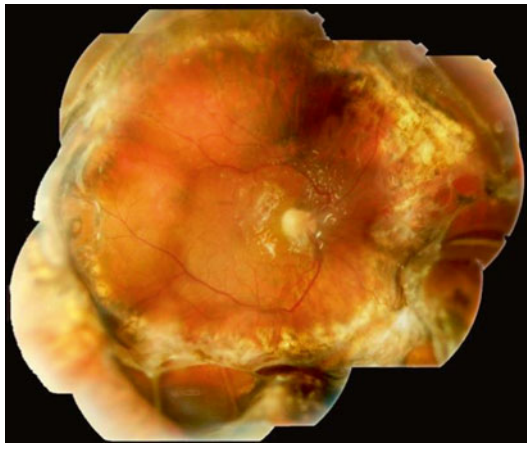
In PVR cases, the most commonly used intraocular tamponades are long-acting gas mixtures,



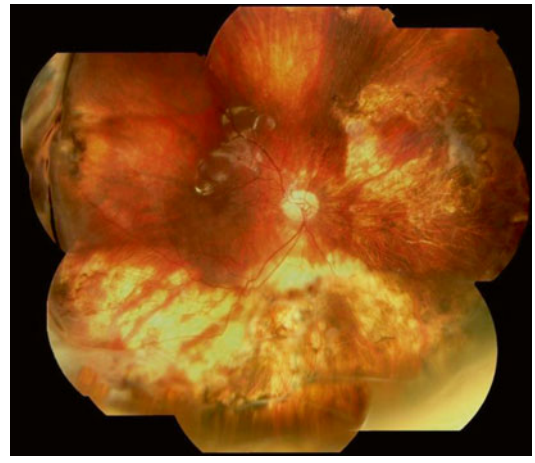
Case 2a Complex PVR case showing epiretinal and subretinal membranes



Case 3a Complex PVR case with prominent epiretinal and subretinal components



Case 2b Same patient showing complete reattachment after epiretinal and subretinal membrane dissection, circumferential buckle, and 360º retinotomy with SO tamponade



Case 3b Same patient showing complete retinal reattachment. Dissection of subretinal membranes was achieved through a superior nasal retinotomy. Circumferential buckling and epiretinal membrane dissection were performed previously to an inferior relaxing retinotomy

such as 15 % perfluoropropane or silicone oil. Advantages and disadvantages of these substances are listed in Table 5.4.

Intraocular gas can be replenished postoperatively if the vitreous fill is inadequate or absorbing too quickly as an outpatient procedure. All sclerotomies should be sutured when using SO or in cases of 23G vitrectomy in eyes with a thin sclera or young patients.

5.5.12 Silicone Oil

Silicone oil is injected via a pars plana sclerotomy site through a specially designed rigid 10 ml reinforced syringe attached to a 20G or 23G intravenous catheter that has been cut to about 1 cm in length. The SO is injected under pressure from an

Table 5.4 Comparison of perfluoropropane gas versus silicone tamponade for proliferative vitreoretinopathy

Tamponade	Advantages	Disadvantages
Perfluoropropane (C3F8)	Absorbs spontaneously	No intraocular tamponade 6–8 weeks after surgery
	Control duration of tamponade from intermediate to long duration by adjusting concentration of C3F8 with air	Air travel prohibited until bubble is absorbed
	Visual rehabilitation occurs more rapidly	Cataract formation if prone positioning not maintained
	Relatively few long-term complications associated	Short-term complications, such as elevated IOP
Silicone oil (SO)	Extended tamponade for months or years, allowing surgeon to determine if and when to remove it	Does not prevent reproliferation in inferior retina
	No restrictions on air travel	Slow visual rehabilitation and significant changes in refraction
	Compensates hypotony	Significant complications: corneal toxicity, cataract formation, elevated intraocular pressure, silicone oil emulsification
		Must be removed by a second surgical procedure to achieve best visual acuity

air pump in the vitrectomy machine. This surgical step should be performed under direct visualization with a wide-angle viewing system, while air infusion is still connected to the eye. As SO enters the eye, the infusion pressure is lowered to 10–15 mmHg, enabling us to control intraocular pressure. Once the oil level reaches the infusion cannula, IOP may rise suddenly. This is avoided by removing the air infusion cannula at this stage and gently continuing the SO injection until all the air is expressed out through the sclerotomy site.

In aphakic eyes, a basal iridectomy at 6 o'clock position is recommended to prevent postoperative pupillary block and secondary glaucoma.

In cases of large retinotomies, we usually prefer a direct exchange PFCL–SO injection in order to lower the risk of posterior displacement of the retinotomy edge to the posterior pole. Aspirating all the subretinal fluid anterior to the PFCL level before performing the direct exchange is important to prevent retinal folding or displacement.

PVR cases should be monitored postoperatively to look for recurrent traction or retinal breaks. If the eye is quiet and all peripheral retinal pathology well supported by a high scleral buckle, silicone oil may be removed after approximately 3 months. Wound healing sequence of PVR membranes takes 3 months to develop, and SO should be maintained for at least that length of time. After SO removal, there is a potential risk of retinal redetachment, specially in cases with previous unsuccessful surgeries or longer axial length [28]. Additional 360° laser posterior to the encircling buckle may decrease this risk in PVR cases. Delayed removal of SO up to 18 months does not improve anatomical outcomes, and it can impair the functional outcome by precipitating the development of a persisting secondary glaucoma due to SO emulsification [29]. Late glaucoma is usually an indication to remove all the SO.

Cataract progression occurs usually within 6–18 months after SO tamponade. Combined phacoemulsification of the lens, insertion of an intraocular lens, and removal of SO can be carried out at the same time.

Silicone oil is removed with controlled active suction through a 20G or 23G cannula under air infusion into the vitreous cavity to maintain IOP during the procedure. The last of the silicone is removed by rotating the eye so that the residual bubble floats out. Some surgeons do repeated fluid–air exchanges to ensure that residual small bubbles of SO are removed.

Some PVR cases with multiple previous surgeries, however, have relatively poor visual potential despite a flat macula, but evidence of persistent peripheral scar tissue or localized retinal detachment under SO tamponade. In these circumstances it is generally wiser to leave the SO in situ.

5.6 Complications in PVR Surgery

PVR is a very serious complication of retinal detachment, and patients should be informed of the possibility of a low functional result despite an anatomically successful surgery. Intraoperative and postoperative complications are more frequent in PVR cases, and an extra caution should be taken in these cases.

5.6.1 Intraoperative Complications

- Bad visualization: it can be due to several causes:
  - Corneal edema: we can relieve it by scrapping the corneal epithelium or decreasing intraocular pressure.
  - Pupillary constriction: use 1:10.000 epinephrine in the vitrectomy infusion or flexible iris retractors.
  - Cataract clouding: perform lensectomy via pars plana.
  - Intraoperative bleeding: common when performing retinotomies or during dissection of dense membranes. We can control it by raising temporarily the infusion pressure. We can prevent it by performing endodiathermy on main blood vessels before creating a retinotomy.
- Pass of air or heavy fluid into the subretinal space through a retinal break: further relief of retinal traction usually allows to aspirate these materials and reattachment of the retina. It may require retinotomy and further exchanges to flatten the retina after complete mobilization.
- Serous choroidal detachment: it is usually due to a misplaced infusion cannula under the retina. It should be managed by transferring the infusion to another sclerotomy port.
- Choroidal hemorrhage: initial management by increasing intraocular pressure and occlusion of sclerotomies by taps or surgical instruments in an attempt to limit the extent of hemorrhage. Valved microcannulas are highly recommended, as they allow us a better control over the fluidics and avoid sudden hypotony, which is the major cause of choroidal hemorrhages. If a large choroidal hemorrhagic detachment develops, we should avoid performing an external drainage at the same time; this maneuver causes a transient hypotony, and that may stimulate choroidal rebleeding.

5.6.2 Early Postoperative Complications

- Increased intraocular pressure is the most common complication, occurring in 10–15 % of cases [30]. Initial treatment may start with ocular hypotensive drops or oral acetazolamide. Consider an overfilling of the eye with gas or SO if the eye has a shallow anterior chamber. Removal of a small amount of gas can be performed through the pars plana with a 30G needle. Removal of SO should be performed in the surgical room.

  In aphakic eyes filled with silicone, an increase in intraocular pressure may be due to an incomplete inferior iridectomy or blocking of it with the lens capsule.
- Postoperative inflammation should be initially treated with topical or systemic steroids. We can prevent it by using subtenon steroids at the end of the surgery of PVR cases. Tissue plasminogen activator injection may also be used in the postoperative period when a dense fibrin material occludes the pupil.
- Incomplete filling of ocular tamponade: it can be due to leakage of a sclerotomy or errors of gas concentrations. We should refill the vitreous cavity with gas after checking the sclerotomy ports.

5.6.3 Late Postoperative Complications

- Regrowth of epiretinal membranes: they can lead to retinal redetachment or tractional retinal tears or, if milder, to macular pucker. Previous studies reported retinal redetachment of PVR cases in 25–50 % of cases [30, 31]. This incidence has decreased with the improvements in visualization, instrumentation, and surgical techniques as an aid to relieve all retinal traction.

  Perisilicone proliferation: one usual situation is an inferior recurrence of retinal detachment in association with silicone oil. Even in cases with a complete fill of SO, a small meniscus of vitreous fluid persists inferiorly when the patient is in an upright position. The accumulation of proteins and inflammatory and metaplastic cells in this area can lead to further reproliferation on the retinal surface in 50–60 % of cases [32]. If the macula stays attached, it is advisable not to perform a reoperation. If the fluid threatens useful macular function, then reoperation with further dissection of membranes, retinectomies, or supplementary indentation should be considered [33].

  Macular pucker occurs in PVR eyes in 5–15 % of cases [34]. ILM extraction decreases the risk of macular pucker formation in the postoperative period. Peeling should be considered if there is significant visual potential and can be done behind SO, without removing it.

  Anterior surface proliferation may exert traction on the ciliary body and cause ocular hypotension. In selected cases it may justify further surgery to perform relaxing retinectomies and peeling of membranes to release the ciliary body [35].
- Retained heavy perfluorocarbon fluid under the retina: it usually locates inferiorly with gravity. It can be left in the vitreous cavity if small in volume, but needs to be aspirated from the anterior chamber. If it affects the posterior pole, it can be removed with an additional surgery by suction through a 39G subretinal cannula [36].
- Silicone oil complications:

  Emulsification into fine bubbles: it is more common with the lower viscosity material (1,000 cSt). If limited to the posterior segment, it can be left alone. If it passes into the anterior chamber, they can block the angle and lead to secondary glaucoma or can damage corneal endothelial function. In aphakic eyes it can lead to band keratopathy in up to 27 % of cases [37], although its incidence is less if an in-the-bag intraocular lens and a circular capsulorrhexis are present. If we remove emulsified SO droplets in the anterior chamber by irrigation and aspiration, we should take into account that further oil tends to flow through from the vitreous cavity. In these cases, SO usually needs to be removed completely from the anterior segment and vitreous cavities and, if still required, replaced with fresh SO.

  Cataract is universal in phakic eyes following vitrectomy and extended silicone tamponade. Some surgeons advocate phacoemulsification and replacement of the lens routinely at the time of surgery for PVR, as this may facilitate dissection of the vitreous base.
- Iris neovascularization: can occur in recurrent persisting retinal detachment and intraocular inflammation.
- Cystoid macular edema: standard treatment with topical steroid and nonsteroidal drops, intravitreal triamcinolone injection, or dexamethasone intravitreal implants.
- Scleral buckle-related complications: surface scarring around the muscles may lead to diplopia. If an exposed or infected scleral buckle needs to be removed, prophylactic 360° laser posterior to the buckle and silicone oil tamponade may be carried out to ensure that retinal redetachment does not occur.

5.7 Medical Adjunctive Therapy for PVR

Multiple pharmacologic therapies have been used to decrease the risk and recurrence of PVR after retinal detachment surgery [38]. Steroids and antiproliferative agents (low molecular

weight heparin and 5-fluorouracil) have been essayed for this purpose, although they show a limited effect on the final results [39]. Hopefully, new agents designed to block specific targets on the PVR cascade using antibodies, RNA interference, or gene therapy will emerge.

5.8 Results of Surgery for PVR

When comparing different series it is important to note which series may include eyes of different severity and consider different enrolment criteria.

The anatomical success, which is defined as retinal reattachment for at least 6 months, has progressively improved over the last decades due to the improvement in surgical techniques and instrumentation. However, many eyes need more than one surgical intervention because of persisting cellular proliferation and retinal traction. Functional success is usually limited in these cases, as the multifactorial inflammatory events associated with PVR may lead to apoptosis of the retinal cells [12]. In a multicentric and controlled study, the silicone study, about 50 % of cases, either with gas or SO, obtained 5/200 vision or better [28]. If the SO could be removed, after SO extraction eyes were 19 times more likely to experience a visual acuity improvement of ≥3 lines. However, SO extraction caused a recurrent retinal detachment in 19 % of cases [40]. There was no statistically significant difference in the anatomical reattachment rate or visual acuity between 14 % perfluoropropane gas tamponade and SO after a long-term follow-up up to 6 years [31, 40].

5.9 When Is Surgery for PVR Not Justified?

A cost-utility analysis of surgery for PVR reasoned that it was cost-effective to perform a complete range of surgical interventions and multiple procedures in cases where there is low vision in the fellow eye, as a large majority of cases can be expected to recover reasonable mobility vision [41]. If the fellow eye has normal vision and the affected eye has a severe form of PVR with chronic retinal detachment and no hope of macular redemption or with failure after previous surgeries with SO injection, it could be justifiable to advise against any further surgery. The decision must be flexible and is dependent on the patient after understanding the expectations and possible outcomes of surgery in these complex cases. Initial visual acuity helps us to decide in most cases: no light perception is our major criteria for rejecting any further surgery, although in severe trauma with both eyes similarly affected, surgical intervention can be considered.

Hopefully, new investigations will increase our understanding of the cellular and molecular changes that occur in the PVR process and together with new advances in fine instrumentation and surgical techniques will lead to a change in the outlook of these complex cases.

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Surgical Management of Proliferative Diabetic Retinopathy

6

Jason Hsu, Sonia Mehta, and Allen C. Ho

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J. Hsu, MD (✉) • S. Mehta • A.C. Ho
Retina Service, Wills Eye Hospital, Philadelphia, PA, USA
e-mail: jhsu@midatlanticretina.com; smehta@midatlanticretina.com; acho@midatlanticretina.com

6.1 Preoperative Considerations

Anti-vascular endothelial growth factor (VEGF) antibody therapy is an important consideration prior to surgical intervention in patients with PDR. Currently, off-label bevacizumab is the most frequently used anti-VEGF agent, but ranibizumab and aflibercept are equally efficacious. Although dosing can vary, a typical intravitreal bevacizumab dose of 1.25 mg administered in 0.05 ml is sufficient. These agents induce rapid regression of neovascular vessels and have several benefits from a surgical perspective. With less dilated neovascular vessels, there is often a decrease in the amount of intraoperative hemorrhage, which allows for improved visualization of the retina and tractional membranes during membrane dissection. Due to the regression of the neovascular "pegs," membrane delamination is often easier to perform.

However, certain caveats exist with anti-VEGF use. In particular, the rapid regression of the neovascular vessels may lead to membrane contraction and worsening TRD. As a result, intravitreal anti-VEGF injections should generally be done within a week or less of

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planned surgery. Patients should be warned about the importance of following-up for surgery as planned once an injection is given, which can sometimes be problematic in this population of sicker patients. Prior to proceeding with the injection, all preoperative admission testing and clearance from the patient's medical physician should be obtained to ensure the patient is cleared for surgery and lower the likelihood of postponement.

Strongly consider the use of an intravitreal anti-VEGF injection in patients with known or suspected TRD, significant active neovascularization or neovascular membranes (especially if panretinal photocoagulation has not been completed), and dense vitreous hemorrhage. In some cases, even membranes that appear relatively avascular can still have active underlying neovascular pegs. As a result, keep a low threshold for using anti-VEGF therapy.

6.2 Surgical Techniques: Approach to Vitreous Hemorrhage Without Tractional Membranes

6.2.1 Isolated Neovascularization of the Disk (NVD) with Vitreous Hemorrhage

Often, significant vitreous hemorrhages can occur in these situations due to the separation of the posterior hyaloid from the retina. Due to the presence of NVD, a complete posterior vitreous detachment (PVD) usually does not occur. Rather, the hyaloid begins to pull on the NVD causing the VH. In such a situation, it is often easier to release the anterior-posterior traction on the NVD by starting the core vitrectomy in the midperiphery and separating the posterior hyaloid from the vitreous base. Once this is completed, continue to trim the hyaloid and vitreous hemorrhage back toward the optic nerve. A tuft of NVD should be left over the optic disk (Fig. 6.1). Trying to induce a PVD often leads to significant hemorrhage from the NVD which cannot be safely cauterized due to the fact that these vessels lie on the surface of the optic nerve. By leaving a tuft of hyaloid/NVD, this limits any new hemorrhaging. In addition, judicial diathermy can be more safely applied, if necessary, to any oozing neovascular vessels at the edge of the tuft (Fig. 6.2). However, use diathermy near the optic nerve with high caution since this can induce optic neuropathy.

Any residual preretinal hemorrhage can then be aspirated using the vitrectomy instrument. Rather than placing the cutter close to the retina and risking potential iatrogenic injury, one can

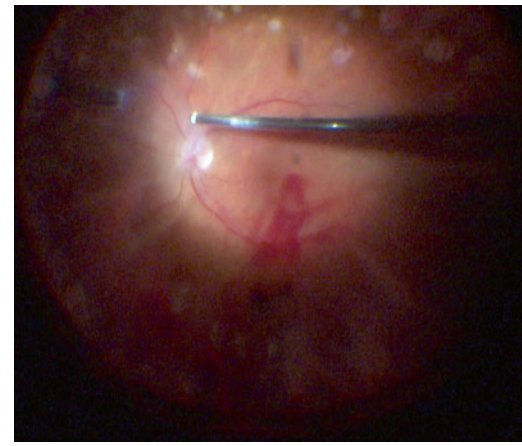

Fig. 6.1 Intraoperative photograph demonstrating the use of the cutter to release the vitreous from the disk neovascularization

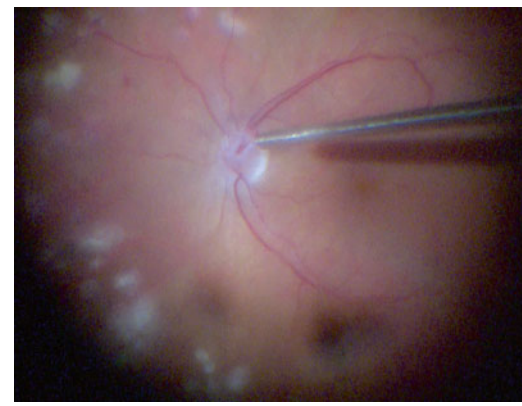

Fig. 6.2 A 23-gauge intraocular diathermy is used with low energy to lightly cauterize the edge of the disk neovascularization

aspirate in the mid-vitreous cavity while directing the infusion cannula toward the area of hemorrhage. The infusion jet stream will then disperse the hemorrhage from the retinal surface.

6.2.2 Approach to Dense Vitreous Hemorrhage

In these situations, a B-scan is imperative preoperatively for surgical planning and in order to ensure that an underlying retinal detachment (RD) is not present. Even with confirmation of no RD, it is important to proceed cautiously as visualization may be limited, and it can be difficult to distinguish hyaloid from retina in some situations. The core vitrectomy, when possible, should be started in the superior half and proceed layer by layer until the location of the retina is confidently confirmed. This is useful in situations where an unforeseen RD is present under the hemorrhage as creating an iatrogenic break in superior retina will be easier for tamponade. Once an opening in the posterior hyaloid has been made and the retina visualized beneath, the cutter should be kept at the edge of the hyaloid and continue to enlarge the opening. Shaving of the inferior vitreous base under scleral depression may be helpful in these cases as much of the blood will have pooled inferiorly by gravity. By shaving down this area, much of the hemorrhage that tends to leach out postoperatively is removed, often allowing for a faster visual recovery postoperatively.

6.3 Surgical Techniques: Approach to Traction Retinal Detachment

TRDs represent some of the most challenging cases in vitreoretinal surgery. The approach that needs to be taken for a successful outcome varies, and no one approach works for all cases. Oftentimes, creativity is essential.

Typically, at least some parts of the hyaloid will be elevated outside the retinal vascular arcades as this is the underlying mechanism leading to the tractional detachment. In this situation, the anterior-posterior traction can be relieved first by incising the elevated posterior hyaloid in the midperiphery then trimming it down toward the edges of the membranes. Once the hyaloid has been trimmed, attention can then be directed toward dissecting the remaining membranes.

Alternatively, it may be helpful to initiate dissection of fibrovascular membranes around the optic nerve and then move outward. Diabetic traction retinal detachment often extends from the optic disk outward and along the retinal vascular arcades. Since the retina is thicker and less fragile near the optic nerve, this is another good option for approaching a TRD.

Although the appearance of the fibrovascular membranes can appear as sheets of contracted tissue detaching the underlying retina, the cross-sectional anatomy usually reveals that the retina is attached to the membranes by focal "pegs" (previous areas of NVE) rather than by broad adhesion to the retina. The most efficient membrane dissection, therefore, first identifies the open areas between the fibrovascular membranes and the retina and, secondly, identifies the adjacent "pegs" which may be detached from the retina with the vitrectomy cutter itself or one of several techniques described below.

6.3.1 Bimanual Techniques: Lighted Pick

Using a forceps in one hand and a lighted pick in the other hand, the hyaloid/membrane can be pulled up in order to identify the underlying pegs (Fig. 6.3). The pick is used to sweep back and forth across these pegs to assist with delamination. The bottom platform of the pick may also be used to apply gentle countertraction simultaneously on the retina as the membrane is being pulled. This enhances visualization of the pegs during dissection. The lighted pick can also be used in conjunction with the vitreous cutter itself to manipulate and cut away fibrovascular membranes while simultaneously creating a safe zone of underlying retina beneath the pick blade.

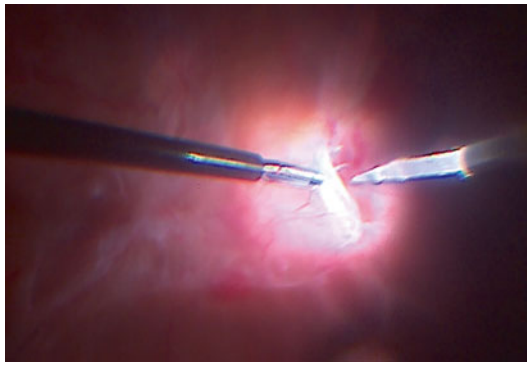

Fig. 6.3 Intraoperative photograph demonstrating use of the lighted pick in combination with forceps for delamination of membranes from the retina surface

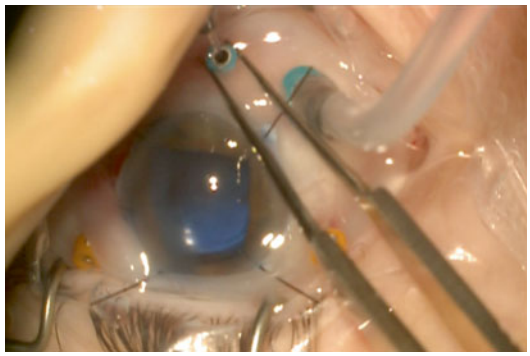

Fig. 6.4 Insertion of a 25-gauge chandelier through a self-retaining cannula

6.3.2 Bimanual Techniques: Chandelier

A chandelier provides excellent diffuse lighting, allowing both hands to be used for membrane dissection (Fig. 6.4). Typically, a forceps is used in one hand to grasp the membrane, while a second instrument may be chosen to assist with delamination and segmentation of the membranes. With the advent of small-gauge vitrectomy instruments, several enhancements have been made to the cutter, including a wider mouth and displacement of the opening toward the tip. These factors allow the cutter to be used almost like a vertical scissor. The neovascular pegs are identified by gently lifting the edge of the membranes with the forceps. The mouth of the cutter can then be used to engage the peg and release the attachment between the membrane and retina. Minimal aspiration is typically necessary, and a low cut rate will often suffice.

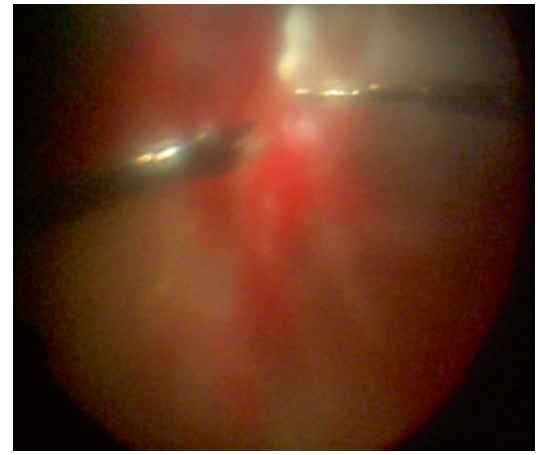

Fig. 6.5 Using a chandelier for illumination, delamination of membranes can be accomplished with forceps and a curved horizontal scissors

Another useful instrument is curved horizontal scissors, particularly when broad areas of fibrosis are present. Using forceps in one hand, the edge of the membrane is lifted. The scissors can be used to perform blunt dissection by placing the tips closed in the space between the retina and membrane and spreading (Fig. 6.5). As the neovascular pegs are identified, these can be directly cut by the scissors with a gentle lifting technique, lowering the risk of iatrogenic breaks related to traction. Scissors can also be used for segmentation by simply tilting the scissors and directly engaging and cutting the membrane. Recently, pneumatic scissors have been introduced which allows the surgeon to use the foot pedal to control the opening and closing of the instrument. This further enhances the stability during membrane dissection, allowing for greater precision and control.

6.3.3 Viscodissection

Viscodelamination was originally described by Stenkula and Tornquist in 1983 as a technique for removal of epiretinal membranes [1]. However,

McLeod and James were the first to report success with viscodissection in tractional retinal detachments from proliferative diabetic retinopathy [2]. Hubbard and Fortun modified the technique for microincisional vitrectomy and were the first to report use of the viscodelamination instrument which improved access, maneuverability, technical ease, and allowed for surgeon-controlled delivery of the viscoelastic [3]. In this technique, viscoelastic is used to separate the posterior hyaloid and fibrovascular membranes from the subjacent retina. This technique is particularly useful for tractional retinal detachments with broad attachments between the fibrovascular membranes and retina, in combined tractional and rhegmatogenous retinal detachments (Fig. 6.6a), and in cases where there is minimal or no separation of the posterior hyaloid.

A 23- or 25-gauge vitrectomy setup is employed. The viscodelaminator instrument (Peregrine Surgical Ltd, Doylestown, Pennsylvania) has an extendible, curved 25-gauge nitinol probe [1]. It is connected via short tubing to a 10-mL syringe partially filled with 1 cc of ProVisc viscoelastic (ProVisc; Alcon Laboratories, Inc., Fort Worth, Texas). The syringe is then connected to the viscous fluid injector system so that injection of the viscoelastic can be controlled with the vitrectomy foot pedal similar to silicone oil injection. The tubing is primed outside of the eye and the settings

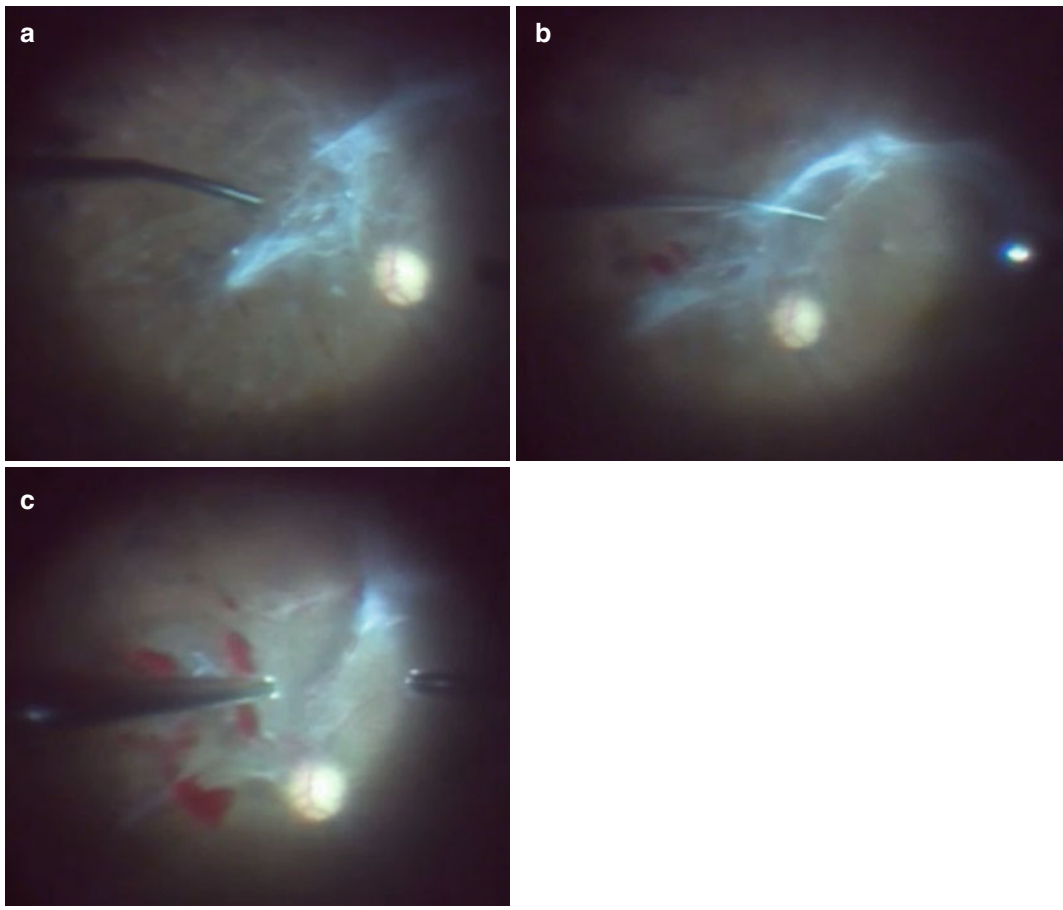

Fig. 6.6 (**a**) Preoperative fundus photograph demonstrating a tractional retinal detachment from proliferative diabetic retinopathy. Note the broad attachments between fibrovascular membrane and retina. (**b**) Intraoperative fundus photograph demonstrating viscodissection with 25-gauge viscodelaminator instrument. (**c**) Intraoperative fundus photograph demonstrating the same area following membrane dissection and removal with the vitreous cutter

adjusted to allow for a slow and steady flow. A core vitrectomy is performed, and then a small opening is created in the posterior hyaloid in the midperiphery adjacent to the proliferative membranes using the vitreous cutter (Fig. 6.6a). Attention is given to preserve the continuity of the posterior hyaloid and membranes so as to utilize the anterior-posterior forces of vitreous traction to assist in the dissection and separation. Maintaining posterior hyaloid continuity also allows for the viscoelastic to be contained. The viscodissection instrument is inserted into the eye, and the viscodissection cannula is extended through the small opening in the posterior hyaloid so the tip is parallel with the retinal surface. A parallel tip can help reduce the chance of creating a retinal break and injecting viscoelastic into the subretinal space. The viscoelastic is injected in a controlled fashion dissecting the posterior hyaloid and fibrovascular membranes from the retina (Fig. 6.6b).

Once the posterior hyaloid and fibrovascular membranes have been dissected from subjacent retina, the membranes and vitreous can be removed "en bloc" using the vitreous cutter (Fig. 6.6c). The peripheral vitrectomy can then be completed and panretinal endolaser photocoagulation applied.

6.4 Surgical Techniques: Approach to Subhyaloid Hemorrhage Without Tractional Retinal Detachment

Subhyaloid hemorrhage typically occurs in younger patients due to traction on neovascular vessels with incomplete posterior hyaloid separation. In many cases, there may only be limited separation of the hyaloid over parts of the macula with much of it being pegged down by neovascular fronds. The peripheral hyaloid is rarely separated in this situation. The ideal surgical goal is to release all the pegs from the hyaloid, allowing for complete posterior vitreous detachment. However, more often than not, this may not be safely possible or easily accomplished.

Following core vitrectomy, it is helpful to start in an area of posterior hyaloid separation, which can often be discovered over the macula. Once an opening has been created, the hyaloid and membranes can begin to be lifted up carefully, usually in a more controlled fashion with forceps rather than suction from the cutter. Care must be exercised not to place undue traction on neovascular fronds, which can lead to significant hemorrhage and iatrogenic breaks. As the hyaloid and membranes are lifted, the neovascular pegs must be separated to allow safe release. If anti-VEGF therapy was given preoperatively, some smaller pegs will often release with gentle traction using forceps on the hyaloid/membranes or careful aspiration and lifting with the cutter. However, larger fronds will typically require more direct dissection, as described in the traction retinal detachment section.

6.5 Surgical Pearls

6.5.1 Membrane Peeling

While the concept of complete removal of fibrovascular membranes may be aesthetically pleasing to the surgeon, the reality is that significant hemorrhage may occur with overaggressive delamination attempts. The key principle in TRD repair is relief of traction. Therefore, relief of anterior-posterior traction by releasing the hyaloid from the edges of the membrane and relief of tangential traction through segmenting the membranes are the primary goals. During the delamination process, smaller and more whispy pegs can be released, but larger fronds with thicker trunks are often not easily released and pose the highest risk of significant hemorrhage with manipulation. Segmentation around these thicker trunks should be strongly considered.

Similarly, once tissue has been segmented, it is often prudent to leave a "stump" of fibrous tissue to decrease the risk of hemorrhage. A safe way of trimming these residual membranes is placing the cutter on top of the segmented membrane and briefly depressing the foot pedal to full treadle ("depression delamination"). This will often pull the edges of the membrane into the cut-

ter while lowering the risk of causing an iatrogenic break. Diathermy can be applied at the edge of these membranous stumps if any oozing occurs. In contrast, if these stumps are completely removed, significant hemorrhage may occur which can only be stopped by diathermy directly to the retinal surface.

6.5.2 Intraoperative Hemorrhage

Controlling hemorrhage during these cases can be challenging. Significant hemorrhage can have multiple negative effects. Visualization of the retina becomes impaired, increasing the risk of iatrogenic breaks. Patients have a higher risk of postoperative vitreous hemorrhage, which may be non-clearing. In cases where silicone oil is used, continued hemorrhaging after oil instillation may increase the total volume posteriorly, causing elevated intraocular pressure (IOP). In some cases, residual hemorrhage is a nidus for additional membrane formation.

While increasing the IOP to 60 mmHg or more is typically the first thing to do when significant hemorrhage begins, it is not uniformly effective at stopping the bleeding. Diathermy should be judiciously applied as soon as possible to limit further hemorrhage. It is important to keep in mind that these patients typically have severe vascular compromise and ischemia, potentially increasing the risk of vision loss with prolonged length of time at high IOP.

When retinal hemorrhage persists despite tamponade IOP, a blunt instrument such as the cutter can be placed on top of the point of hemorrhage, analogous to applying pressure to a bleeding cut. This can help control the hemorrhage until diathermy is applied. This maneuver works best with bimanual technique. A chandelier is used for lighting, allowing the surgeon to hold the diathermy in one hand and cutter in the other. The cutter is used to help aspirate the hemorrhage and identify the source of the bleed. Once identified, gentle pressure is applied using the back of the cutter (no aspiration or cutting). After a few moments, the diathermy may be used to permanently stop the bleeding.

Another useful technique involves laser photocoagulation. Persistent oozing of blood can sometimes be controlled with lower intensity and longer duration laser photocoagulation to promote the development of a coagulum at the site of bleeding.

Finally, these patients often have significant hypertension as well as underlying coagulopathies, which may contribute to intraoperative hemorrhage that is difficult to control. It is important to communicate with the anesthesia staff and, when safe, see if they can help improve intraoperative blood pressure control. In some cases, this will help decrease the bleeding.

6.5.3 Take Advantage of the Cannula System

Surgical planning prior to the start of these complex cases can greatly improve the ease and efficiency, saving valuable time. Small-gauge vitrectomy systems with self-retaining transconjunctival cannulas should be strongly considered for these cases. Placement of the cannulas should be determined based on ease of access to the main membranes that require dissection. In addition, patient anatomy is an important consideration. For example, placing the cannulas in a very horizontal position such as at 3 and 9 o'clock can be disastrous in a patient with a prominent nasal bridge as it will be very difficult to maneuver instruments that are placed in the nasal cannula into the proper position.

Another benefit of the cannula system is the ability to interchange infusion site quickly (Fig. 6.7). This frees the surgeon to use any of the cannulas for instrumentation. When dealing with superior peripheral fibrovascular plaques, access can sometimes be challenging through the traditional superotemporal and superonasal sclerotomies/cannulas. In this situation, the infusion can be easily moved to the superonasal cannula, allowing the surgeon to sit temporally and place instruments through the superotemporal and inferotemporal cannulas. This approach helps optimize the angle for membrane dissection.

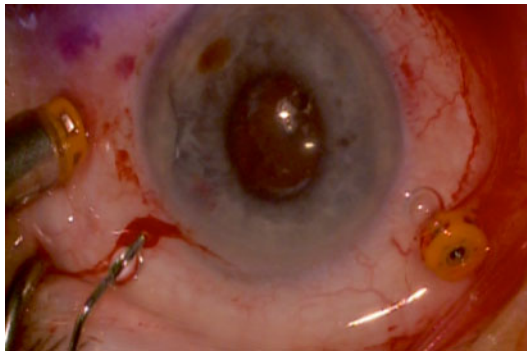

Fig. 6.7 Infusion cannula has been moved superonasally, allowing the surgeon to sit temporally and use the superotemporal and inferotemporal cannulas for instruments

6.5.4 The Vitrectomy Cutter as a Multifunctional Tool

With the advent of small-gauge vitrectomy cutters, there have been several design enhancements that have greatly improved the usefulness of this instrument for multiple situations, especially for TRD repairs. The mouth of the 23- and 25-gauge cutters is wider and displaced toward the tip of the instrument. In addition, the shaft has been reinforced, giving it a much stiffer feel. More recently, 27-gauge vitrectomy systems have become available. Some surgeons now advocate the use of these vitrectomy cutters for complex diabetic vitrectomy because of the enhanced ability to access the small space between tissue planes of fibrovascular membranes and the underlying retina.

These features allow the cutter to be used as a great pick. The mouth of the cutter can be placed between the membrane and retina without any vacuum or cutting. Once engaged, the membrane can often be elevated which is helpful when looking for a good plane to begin segmentation. At this point, the cutter can be engaged and segmentation can proceed.

Alternatively, the cutter can also be used for delamination. Using bimanual technique with a chandelier, the membranes can be grasped and elevated using a forceps. This allows identification of the underlying neovascular pegs. The cutter can be used as the second instrument. Careful blunt dissection may also be performed by using the cutter to sweep back and forth between the membrane and retina, allowing visualization of the tougher neovascular pegs. Next, the mouth can be brought adjacent to the peg, and the cutter can be engaged with low suction to transect the peg, thereby further releasing the membrane from the retina. Care should be taken to always be cognizant of where the mouth of the cutter is pointing. Rather than turning it completely toward the neovascular pegs, a safer method is to have the mouth pointing anteriorly (away from the retina) but slightly turned into the peg prior to engaging the cutter, essentially using the side of the cutter's mouth. This lowers the risk of creating iatrogenic breaks.

Another useful technique briefly mentioned before is "depression delamination" whereby the vitreous cutter is placed on top of fibrovascular membranes, depressing an epicenter of tissue to allow folding back of the membranes into the mouth of the cutter. This technique is effective for removing residual membranes from pegs once the edges of the membrane have been released and also lowers the risk of iatrogenic breaks since the mouth of the cutter is pointing away from the retina.

6.5.5 Endoscopic Vitrectomy

Endoscopic vitrectomy can be useful in select cases where there may be significant media opacity and insufficient pupillary dilation, or where the need for visualization of anterior structures of the posterior segment (Fig. 6.8) can be helpful as in cases where the source of bleeding may not be apparent with wide-angle visualization. One endoscopic unit, Endo Optiks E2 (Endo Optiks, Little Silver, NJ), is a triple function illumination, visualization, and laser photocoagulation system that can be useful to the surgeon.

6.6 Choice of Tamponade

The purpose of tamponade is to restore the transretinal pressure gradient via surface tension in the presence of retinal breaks. In patients with

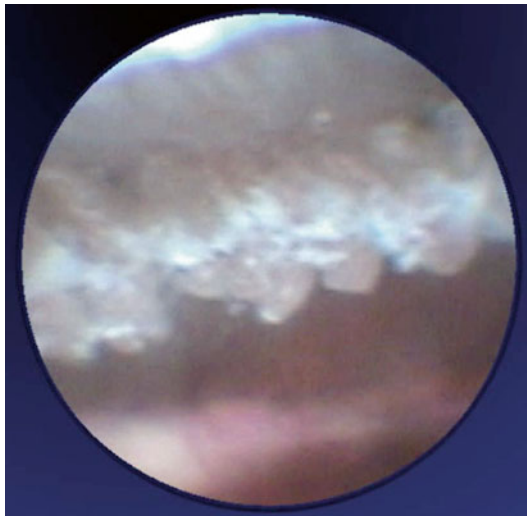

Fig. 6.8 Endoscopic view of pars plana and ciliary processes

tractional retinal detachment and no breaks present at the conclusion of surgery, no endotamponade is typically necessary. However, it is critical to be aware of the possibility of microbreaks, which may be hidden beneath residual membranes. If no endotamponade is used in these situations, retinal reattachment may not occur.

The choice of air or gas is often dependent on the severity and location of breaks. In general, if a retinal break is present or suspected, intraocular air or gas should be used. With multiple breaks especially in the inferior quadrants, a longer-acting tamponade such as perfluoropropane (C3F8) should be considered. Otherwise, a shorter-acting tamponade such as air or sulfur hexafluoride (SF6) may be sufficient.

Silicone oil tamponade should be considered when large breaks, multiple breaks, or a retinectomy are present. Type of silicone oil to use is surgeon dependent as there is no definitive evidence that higher viscosity (e.g., 5,000-centistoke oil) is superior for maintaining retinal reattachment. While there is some evidence to suggest that 1,000-centistoke oil may have a greater tendency to emulsify and be associated with an increased incidence of late elevated intraocular pressure compared to 5,000-centistoke oil, we have had an excellent experience with 1,000-centistoke silicone oil for long-term tamponade use at our institution.

6.7 Postoperative Considerations

Recurrent vitreous hemorrhage or immediate postoperative vitreous hemorrhage can occur following surgery for proliferative diabetic retinopathy. In these cases, ultrasound should be performed to evaluate the retinal status. In cases where the retina is attached and where the fellow eye has good vision, observation is likely best to allow time for the hemorrhage to clear. This may take several weeks to months depending on the patients' phakic status, use of anticoagulants, and cause for bleeding. Patients need to be watched for elevated intraocular pressure from etiologies such as ghost cell glaucoma or hemolytic glaucoma. In cases where the recurrent hemorrhage does not clear on its own in a timely fashion, anti-VEGF injections or reoperation are indicated. The latter is best performed in the operating room using a three-port vitrectomy setup. This allows for potential causes of the bleeding to be addressed such as residual membranes causing traction on vessels or untreated neovascularization. If additional PRP is needed, it can be performed at the same time. Vitreous washouts have also been described as an in-office procedure via a two-needle fluid-fluid exchange or fluid-air exchange.

Anterior segment neovascularization and vitreous hemorrhage in the postoperative period may also be treated with intravitreal anti-VEGF injections. In cases of vitreous hemorrhage, this may allow the hemorrhage to clear and additional laser photocoagulation to be applied if indicated to reduce recurrences.

Anterior hyaloidal fibrovascular proliferation (also known as anterior vitreous cortex fibrovascular proliferation or retrolental neovascularization) can occur following surgery for proliferative diabetic retinopathy. In these patients, fibrovascular tissue occurs anteriorly growing from the peripheral retina to the posterior lens capsule and vitreous base eventually resulting in a peripheral TRD followed by a total RD. These patients

require extensive vitrectomy, thorough vitreous base dissection, pars plana lensectomy, removal of cyclitic membrane, additional panretinal laser photocoagulation, and silicone oil tamponade. These eyes carry a poor prognosis.

Fibrovascular proliferation can occur in the eyes with silicone oil tamponade at the retina-silicone oil interface. Oil emulsification may also occur, which can lead to secondary glaucoma and vision loss. Patients should be monitored for these postoperatively, and surgery may be indicated in significant cases.

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Complications of Tamponades in Vitreoretinal Surgery

7

Mario R. Romano, Jose Luis Vallejo-Garcia, and Heinrich Heimann

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M.R. Romano (✉)
Department of Ophthalmology,
Humanitas Research Institute,
Via Manzoni 56, 20089 Rozzano, Milan, Italy
e-mail: mario.romano.md@gmail.com, romanomario@email.it

J.L. Vallejo-Garcia
Department of Ophthalmology,
Manchester Royal Eye Hospital,
Manchester, UK

H. Heimann
St Paul's Eye Unit,
Royal Liverpool University Hospital,
Liverpool, UK

7.1 Introduction

The use of silicone oil (SO) and heavy liquids in ophthalmology has got numerous advantages, but it is not free of risks. It was firstly introduced in 1962, before the vitrectomy era by Cibis et al. that used SO injections into the vitreous cavity, together with transcleral subretinal fluid drainage, to treat retinal detachments [1]. However, SO did not gain significant popularity before the more widespread use of vitrectomy. Even then SO was limited to otherwise irreversible retinal detachments in patients in which the fellow eye was impaired or at risk due to the high rate of complications [2–4].

Heavy liquids (perfluorocarbons) were first used in the early 1990s as short-term tamponades for complex retinal detachments. Early studies showed toxic effects and various complications [5]. Their role was soon limited to the intraoperative use as an aid to drain subretinal fluid, to flatten the retina and to reduce retinal mobility while performing certain manoeuvres.

Heavy silicone oil (HSO), in the form of fluorosilicone, was also first used in the early 1990s, but it could only be used as a short-term tamponade, not being very useful to treat complex retinal detachments with proliferative vitreoretinopathy (PVR). In the early 2000s,

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perfluorohexiloctane (F6H8) was also used in some studies, but it was soon abandoned due to numerous complications [6]. Approximately in the mid-2000s, new HSOs, Oxane HD, Densiron 68 and HWS 46-3000, demonstrated less complications and better results and managed to become an excellent tamponade for inferior retinal pathology [6].

Nowadays these tamponades are much safer and have become fundamental tools when operating certain types of retinal pathologies. However, they still have a significant rate of complications. We will review the more frequent complications, the potential benefits and the risks of these tamponades.

7.2 Intraoperative Complications

7.2.1 Subretinal Migration of Perfluorocarbon Liquids

Perfluorocarbon liquids (PFCLs) have an intermediate interfacial tension against water at 50 mN/m and a dynamic viscosity of 5.10 mPas [5]. The high specific gravity, transparency and low viscosity of PFCLs make it a useful surgical tool in displacing subretinal fluid. They stabilize the retina during surgical manoeuvres inside the vitreous cavity. The retina, being hydrophilic, prefers to be in contact with water rather than with PFCLs; therefore, the retina forms a meniscus that is convex upward. Moreover, the PFCL bubble tends to remain rounded because the interfacial energy creates a net attraction inwards. These findings prevent PFCLs from reaching the subretinal space [7]. Among all PFCLs, perfluoro-n-octane (PFO) has the highest vapour pressure, which allows, in an open system, a more complete PFO removal during fluid–air exchange.

Despite accurate removal of PFCLs during fluid–air exchange, small amounts of PFCLs can be inadvertently left in the vitreous cavity, and occasionally it gains access to the subretinal space. Reported incidence of subretinal retention of PFCLs after vitreoretinal surgery ranges from 1 to 11 % [8, 9]. The residual PFCL droplets stimulate a macrophagic foreign body response with phagocytosis of PFCLs by retinal pigment epithelium (RPE) cells. Microscopy of tangential sections through the specimen of proliferative membranes shows that swollen RPE cells containing the endotamponade are able to induce an inflammatory reaction [10, 11]. Moreover, if the subretinal PFCL is located under the macula, it impedes contact between photoreceptors and RPE-inducing mechanical damage and interferes with cell metabolism and electrolytic balance. A subfoveal location causes focal toxicity to outer nuclear layers and RPE, which results in permanent scotoma or even full-thickness macular hole formation with visual loss (Fig. 7.1) [12].

7.2.1.1 Risk Factors

(a) Small-gauge vitrectomy with non-valved trocar cannula

It was recently described that there is a 4.5-fold increased incidence of subretinal PFCL in eyes undergoing retinal detachment

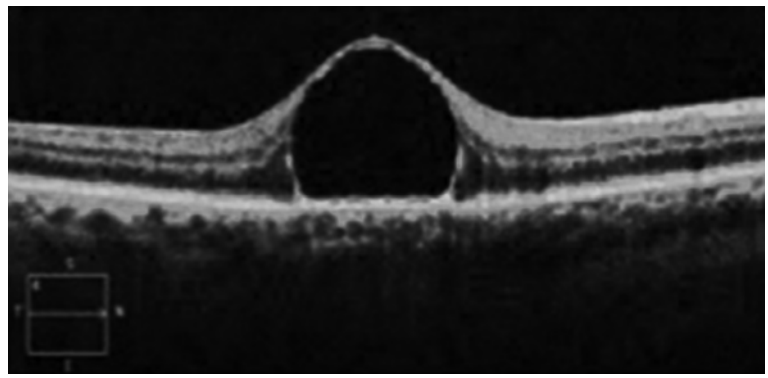

Fig. 7.1 The figure shows PFCL droplets with typical Ω-shaped profile. The superficial tension of the bubble produces an acute angle between the RPE and retina, which differs from a subretinal fluid bubble where the angle between the RPE and retina is obtuse

repair with small-gauge vitrectomy versus traditional 20-G vitrectomy (10.3 %, 4 out of 176 eyes with 23-G group versus 2.3 %, 6 out of 58 eyes in 20-G group) [13]. This may be due to higher fluid flow through smaller infusion lines. In order to optimize the cutting and the speed of the vitrectomy through small-gauge system, we need to use a higher vacuum set (450–650 mmHg) and higher bottle infusion (25–35 mmHg). Such settings generate high turbulence inside the PFCL if the level of PFCL fluid is close to the fluid infusion line. The low viscosity of PFCL, together with the high current of fluid, produces disrupted PFCL surface tension, which results in the formation of small bubbles of PFCL that can easily reach the subretinal space. This phenomenon is less frequent with valved trocar cannula because the trocar flow rate is slower compared to the rapid free flow of fluid that occurs through an open non-valved small-gauge cannula [7].

(b) Incomplete release of retinal traction

In the presence of a retinal break (RB) associated with retinal traction, the specific gravity of PFCL overcomes the superficial tension of the PFCL bubble at the edge of the RB. This creates separation of the bubble that passes through the RB and reaches the subretinal space. The surgeon needs to release the traction on the edge of the RB before raising the level of PFCL above the posterior margin of the RB.

(c) Rapid injection and aspiration of PFCL

The injection and aspiration of PFCL needs to be performed slowly in order to avoid any disturbance of the superficial tension which will result in the formation of "fish eggs" of PFCL. The tip of the cannula should be placed inside the PFCL bubble. During the fluid–air exchange, it is recommended to keep one of the trocars opened (if the trocar is valved to keep open with venting) in order to vaporize the PFCL.

(d) Indentation manoeuvres

During the surgery, the surgeon frequently uses scleral indentation for trimming of the vitreous base or for endolaser treatment of the peripheral retina. The indentation can induce contact between the infusion line and the PFCL; moreover, rapid release of the indentation can generate high suction forces that may draw small PFCL bubbles into the subretinal space. In the presence of PFCL at the edge of RB, the scleral indentation needs to be performed gently with lower and more controlled infusion pressure.

(e) Entrapment in residual vitreous gel

In case of incomplete trimming of the vitreous base or incomplete posterior vitreous detachment, the PFCL can remain entrapped in the vitreous gel and, subsequently, be released during fluid–air exchange or in the early postoperative period. PFCL retained pre-retinally in the vitreous cavity can migrate into the subretinal space during early changes in the patient's posture, and a complete retina–RPE adhesion can develop [14]. The behaviour of such entrapped bubbles is unpredictable.

(f) Extensive retinotomy and direct PFCL–SO exchange

Extensive retinotomy of 120° or larger is highly correlated with subretinal PFCL. During manipulations at the edge of the retinotomy with the flute needle, one can accidently flush PFCL remnants throughout the flute needle [9]. Moreover, in direct PFCL–SO exchange, the peripheral meniscus between the PFCL and SO may come in contact with residual retinal traction, which induces separation of the PFCL bubble that then gains access to the subretinal space.

7.2.1.2 Management

The main objective in managing subretinal PFCL is to minimize retinal damage during extraction. This involves the use of self-sealing small retinotomies performed with small-gauge cannulas. The 50-gauge or 41-gauge cannula is the smallest, but it could take longer to aspirate PFCLs even with high suction because of high resistance to flow [15]. It has been proven that longer aspiration times increase the chance of retinotomy enlargement or retinal or choroidal damage due to involuntary surgeon or patient

movement. The choice of surgical approaches mainly depends on the location and size of the bubble [16].

Other technique is to induce a larger retinotomy (with endolaser or endodiathermy) when the bubble is extrafoveal. In case the location of the bubble is subfoveal, an option is to induce retinal detachment localized at the posterior pole with a 41-gauge cannula injecting balanced salt solution under the retina. Then we inject PFCL in the preretinal space allowing the bubble to move away from the fovea, and the surgeon removes the bubble through a safer retinotomy. In case the PFCL bubble cannot be removed, the patient should be placed on the nasal or temporal side in the presence of light tamponade (air, gas or SO) and then into a face-down position in order to push the subretinal PFCL bubble out the nasal periphery [17].

7.2.2 Sticky Oil Formation

Sticky oil has been described as SO-like material that remains glued to the retinal surface during SO removal [18]. Veckeneer et al. reported sticky oil formation in 28 patients in which 1,000 cSt SO and PFCL was used in the previous surgery. The authors, who used gas chromatography mass spectroscopy analysis, found that there was a significant presence of PFCL in samples of sticky silicone oil, and in all cases, the authors proceeded with direct exchange between PFCL and SO 1,000 cSt [18]. Friberg et al. using electron impact ionization mass spectrometry also reported an interaction between SO and PFCL that dissolves small amounts into solution over time [19]. Sticky oil formation has been described in eyes previously treated with PFCL and light SO and more frequently with PFCL and HSO.

HSO is a mixed compound obtained by adding a semifluorinate (alkane or ether) to SO. The saturation point of HSO is the maximum concentration of semifluorinate that dissolves in SO. HSO is a partially saturated, fluorinated compound and, therefore, more unstable than SO. The presence of PFCL induces changes in saturation points, which alters both the opacity and viscosity of the oil [20]. Solubility equilibrium is also temperature dependent. Changes in temperature change the saturation of HSO by PFCL. Temperature also affects the PFCL–HSO interaction. A decrease in temperature increases opalescence and viscosity of the solution [20].

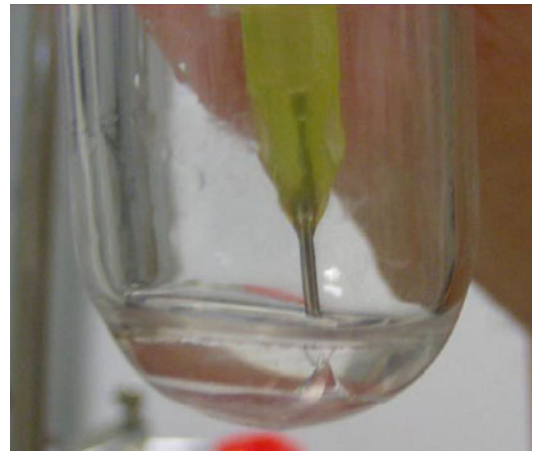

Fig. 7.2 The figure shows the sticky oil formation as a hyperviscous solution obtained by adding PFCL to heavy silicone oil

We demonstrated that the interactions between PFCL and HSO generate a hyperviscous solution with increased shear viscosity and characteristics of that of "sticky oil". In the absence of PFCL, hyperviscous solutions were not formed (Fig. 7.2) [20].

In surgical practice, the direct exchange of PFCL with HSO is not recommended during retinal surgery because of the direct contact between the two compounds at the oil interface.

In a recent paper, Romano et al. showed sticky oil formation in three cases in which direct PFCL–HSO was performed [21]. We believe that the defined sticky oil is a hyperviscous compound produced by interaction with PFCL. At the same time, stickiness of the compound seems to be related to a reduction in the surface tension of the surrounding aqueous material contaminated with PFCL [20]. We demonstrate in vitro that by increasing the temperature, the shear viscosity significantly decreases, with the resolution of the sticky oil [20].

7.3 Postoperative Complications

7.3.1 Emulsion and Inflammation

An emulsion is a mixture of two or more immiscible liquids. There is still some confusion regarding the differentiation between emulsification and opacification. Factors contributing to opacification include water content of SO as well as solvents that dissolve spontaneously in SO and induce phase separation. Real emulsification represents a breakdown of the originally inert bubble of SO into smaller bubbles.

Two liquids can form different types of emulsions. Regarding the compounds currently used in the human eye (oil and water), there can be (a) water-in-oil emulsion, when the water is the dispersed phase and oil is the external phase (eye filled with SO tamponade), or (b) oil-in-water emulsion, when the oil is the dispersed phase and water is the dispersion medium (eye filled with water after SO removal).

7.3.1.1 Detection

Emulsions contain both a dispersed and a continuous phase with the boundary between the phases called the "interface". Micro- and nanoemulsions are scattered and, therefore, visible only if the droplet sizes exceed one-quarter of the wavelength of the incident light (390 and 750 nm). Thus, in the presence of droplets below 100 nm, the emulsion is not visible (no Tyndall effect), and light can penetrate through the emulsion without being scattered. The size of an emulsified SO drop removed from a patient's anterior chamber is around 0.038 mm [22].

7.3.1.2 Formation

Silicone oil stability refers to the ability of SO to resist change in its properties over time.

In the presence of movement (saccadic eye movements), fluids develop at interfaces, and high shear stress is able to overcome the interfacial tension, which induces the formation of droplets.

The stability of a compound and the formation of microemulsion mainly depend on changes in superficial tension (ST) induced by heat, changes in pH level or changes in the viscosity.

7.3.1.3 Surface Tension

Surface tension (ST) is a contractive force in the surface of a liquid that tends to resist external force. This property is caused by cohesion of molecules at the surface that are pulled inward. Minimizations in the sphere shape the necessary "wall tensions", which create forces at the surface to contact the minimized area. The ST is, thus, responsible for the shape and stability of liquid droplets assuming that the SOs used are purified without any irregularity in the manufacturing process.

The surfactants are the main compounds able to lower the ST.

The surfactants are mainly organic, amphiphilic compounds that contain both hydrophobic and hydrophilic groups. Therefore, it contains both an oil-soluble part and a water-soluble part.

At the interfaces, the surfactants will extend in both oil and water with two different tails. The position of surfactants at the interface alters the forces at the surface and prepares the compound for the emulsion. Human eyes with SO tamponade in the presence of two different types of surfactants, biosurfactants and detergents, have been previously described. Biosurfactants are surface-active substances produced by cells. After retinal detachment surgery, biosurfactants such as HDL apolipoproteins, red blood cell membranes and plasma lipoproteins are present at the oil–water interface. The concentration of this substance in the vitreous cavity plays a key role in the formation of emulsification. Overall, HDLs are smaller than LDLs, and when the blood–retinal barrier is broken after surgery, HDLs can reach the vitreous cavity to significant levels [22]. Moreover, RPE cells and fibroblasts also produce biosurfactants such as growth factors and cytokines [22].

The detergents are compounds that are able to solubilize sensible material by dissociating aggregates and unfolding proteins. The detergents are also routinely used to clean and sterilize reusable surgical equipment. Even small quantities of detergents left behind can modify the ST of SO resulting in reduced stability and increased emulsification [23]. Remnants of SO or cleaning substances from the sterilization processes of

reusable equipment can increase the risk of emulsification in SO-filled eyes. The amount of surface-active substances necessary to modify the ST changes according to the patient's eye and also depends on the damage of the blood–retina barrier. The surgical team should be informed of any variations in the cleaning and sterilization process of reusable instruments [23].

7.3.1.4 Viscosity

Viscosity is the measure of the resistance to the deformation induced by shear stress. In a non-Newtonian fluid, such as SO, flow properties are dependent on the relationship between the shear rate (forces applied) and the shear rate (deformation obtained). We can differentiate shear viscosity from extensional viscosity:

(a) The shear or dynamic viscosity is measured as the resistance to flow. The shear stress is the friction induced by a coplanar stress between parcels of the fluid that are moving at different speeds. We currently use kinematic viscosity that is the ratio of the dynamic viscosity to the density of the compound measured in centistokes (cSt).

(b) Extensional viscosity is the measurement of the resistance from the extension of the fibre and breakup of the droplet that is also defined as emulsion. In our surgical practice, the shear viscosity is described as the easiness to inject and remove SO from the vitreous cavity, whereas the extensional viscosity describes the resistance to emulsification.

The easiest way to decrease emulsification, even if it is not the most effective method, is to increase extensional viscosity. Crisp et al. demonstrated that the propensity of SO to emulsify increases according to the proportion of low-molecular-weight components and with decreasing the length of the molecular chain of the compound [24]. Silicone oil 1,000 cSt has a low molecular weight of 37 kDa, whereas SO 5,000 cSt has a higher molecular weight of 65 kDa and, thus, a higher extensional viscosity with less tendency to emulsify. Williams et al. reported a new method to increase the extensional viscosity of SO to keep a low shear viscosity. The authors suggest adding 5–10 % high-molecular-weight (HMW) SO (423 kDa) to 1,000 cSt SO. The resulting SO has the same chemical properties of those used in clinical practices but is more resistant to emulsification and is relatively easy to inject and remove [25].

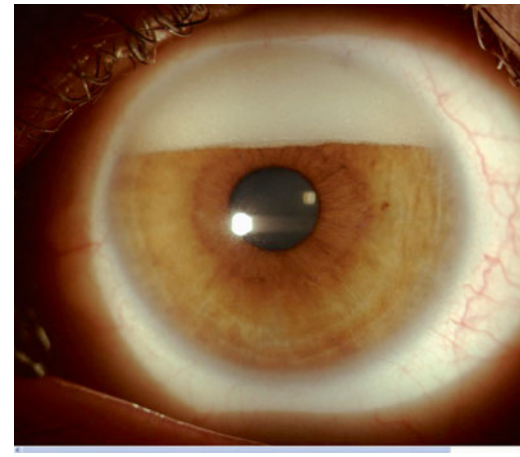

Fig. 7.3 Emulsification in aphakic eye 3 months after 25-gauge pars plana vitrectomy, endolaser and 2,000 silicone oil injection for rhegmatogenous retinal detachment

Caramoy et al. found that the best proportion to attain optimal fluid elasticity is adding 10 % HMW [26]. We believe that such effort can be useful to minimize one risk factor, but emulsification is a more complex phenomenon that cannot be controlled just by viscosity, which is seen by the emulsification still present in our clinical practice (Fig. 7.3).

7.3.2 Migration of Silicone Oil

Silicone oil has a relatively low surface tension than water which is around 40 mn/m. The SO bubble is not able to resist to external forces higher than the ST. In such cases, a small bubble of SO can pinch off from the main bubble and migrate away from the vitreous cavity.

The migration of SO is responsible for decreased tamponade efficiency on the retina and

for side effects related to the contact between SO and anterior segment structures.

7.3.2.1 Subconjunctival Migration

Subconjunctival SO migration occurs more often in patients treated with sutureless 23-gauge vitrectomy. The risk factors are related to inadequate oblique wound construction and scleral rigidity. It is critical to obtain the correct wound with a tunnel long enough to create an internal lip that presses against an external lip. Such construction is able to create self-sealing sclerotomies and also avoids leakage [27]. Scleral rigidity in older patients allows a more effective apposition of the lips when the trocar is removed by the end of the surgery. In younger patients, a more flexible sclera is a risk factor for incomplete closure of sclerotomies. It is important to suture sclerotomies, even 23–25G, if any doubt of leaking is present. A generous final wash of the subconjunctival space with balanced solution to clear every droplet of remaining SO is also recommended.

7.3.2.2 Anterior Chamber Migration

The risk factors for anterior chamber (AC) migration are mainly related to overfilling of the vitreous cavity or to zonular defects in phakic and pseudophakic eyes.

In aphakic eye, sometimes the iridectomy is not enough to avoid AC migration. SO dislocation can be avoided by scleral-fixated artificial iris–intraocular lens [28–30] or by artificial iris diaphragm.

SO displacement in the AC is associated with corneal endothelial damage, secondary glaucoma, cataract progression and adhesion of SO to IOL. The prompt removal of SO is required in such cases. Sometimes it is also necessary to use F4H5 as a silicone solvent to resolve the adhesion between SO and IOL or trabecular meshwork.

7.3.2.3 Subretinal Migration

SO migration into the subretinal space from the vitreous cavity may happen in the presence of strong traction that has not completely resolved before the SO injection. The subretinal localization of SO may result in photoreceptor toxicity with bad visual prognosis. The SO removal from the subretinal space can be achieved by internal or external drainage. Internal drainage needs a large relaxing retinotomy, whereas the transscleral approach seems to be relatively safe and effective [31].

7.3.2.4 Suprachoroidal Silicone Oil

Suprachoroidal SO displacement is due to the iatrogenic location of SO infusion cannula in suprachoroidal space. It is rare to have a separation between the choroid and the sclera induced by anterior proliferation, which allows egress of SO into the suprachoroidal space [32].

The oil can be surgically removed using an internal incision or a transscleral external aspiration. Perfluorocarbon liquid is injected in the vitreous cavity to help the suprachoroidal displacement of residual SO through the existing sclerotomy [33].

7.3.2.5 Intracranial Silicone Oil

Although several reports show the retrolaminar migration of SO microbubbles with subsequent severe optic neuropathy, the risk of extraocular SO penetration remains uncommon and anecdotal. The mechanism seems to be correlated to elevated intraocular pressure (IOP) with macrophages transporting SO through the optic nerve head, which is anatomically predisposed as an optic pit. Subarachnoid or intraventricular migration of SO at MRI has also been described. There is no consensus regarding SO removal from the intracranial space, and the cases reported are always asymptomatic [34–36].

7.3.3 Secondary Glaucoma

High IOP is a common complication after vitreoretinal surgery. The use of SO is related to glaucomatous damage of the optic nerve due to diverse mechanisms, such as mechanical obstruction of the trabecular meshwork or by inducing changes in the draining capacity of the trabecular meshwork.

Pathophysiology	
Secondary angle closure	Overfill with pupillary block
	Anterior migration of SO with mechanical obstruction of the trabecular meshwork
	Rubeosis iridis
	Synechiae with angle closure
Secondary open angle	Emulsification
	Inflammatory response of the trabecular meshwork
	Trigger of an underlying primary open-angle glaucoma
	Ghost cell glaucoma
	Steroid responder glaucoma

Increase of IOP can appear as an early or delayed complication after surgery.

Early postoperative pressure rise is frequently related to SO overfilling, migration into the AC, to surgically related inflammation or the exacerbation of a pre-existing glaucoma.

Possible mechanisms for late-onset glaucoma include emulsified SO that infiltrates the trabecular meshwork, chronic inflammatory changes, synechia formation with angle closure, rubeosis iridis or idiopathic open-angle glaucoma.

7.3.3.1 Incidence

The true incidence is difficult to establish and has been reported between 2.2 and 56 % [37–43]. With recent developments in SO and changing concepts, the rates have diminished when compared to information published in the 1970–1980s, but it is still difficult to provide a more precise incidence rate as most of the retrospective studies have different criteria regarding glaucoma timing and definition. A silicone study report observed a prevalence of long-term elevated IOP at 8 % [40]. The presence of some risk factors may help us to closely follow and give early treatment to those patients if needed.

7.3.3.2 Risk Factors

Studies have identified a variety of risk factors, although the evidence is still unclear and some characteristics have contradictory reports. The main risk factors are:

(a) Silicone oil in the anterior chamber:
   (i) The presence of a bubble of SO in the AC is responsible for the obstruction of the trabecular meshwork [37, 38, 40, 41].
   (ii) Emulsified SO droplets have been clearly associated to an elevated risk of secondary glaucoma [41, 43, 44], although some studies have failed to significantly correlate AC-emulsified SOs with high IOP [38, 40, 45]. We can expect that emulsified oil needs additional factors to increase the IOP.
   (iii) Evidence suggests that high-viscosity SO is less prone to emulsify, and therefore, pressure problems are less likely to happen [38, 45], although this is controversial [46] as noted earlier in the chapter.

(b) Pre-existing elevated IOP

Some studies have found a significant relationship between high preoperative IOP and secondary glaucoma after SO tamponade [43, 44, 47], while other studies could not confirm this [48].

Myopia is an important risk factor for both retinal detachment and glaucoma [49–51]. Miotic drops used to treat glaucoma have also been related to an increased rate of retinal detachment [16]. Patients undergoing vitreoretinal surgery with SO tamponade may also have undiagnosed glaucoma or can develop glaucoma not specifically related to the surgery or the tamponade.

(c) Diabetes

In some reports, diabetes and aphakia were common findings in patients with a rise in postoperative pressure [52]. Henderer et al. [47] also compared isolated proliferative diabetic retinopathy detachments, which had a higher risk for elevated IOP, to PVR rhegmatogenous retinal detachments. The presence of rubeosis of the iris has been frequently related to high postoperative IOP [53]. However, other published reports found that diabetes was not associated with glaucoma [54].

(d) Duration of SO tamponade

It is suggested that the rise in IOP, keratopathy and other complications of SO could be avoided or the progression of these complications could be stopped by removing

the SO a few weeks or months after the injection [18]. In contrast, some studies with long-term follow-up have shown that the increase of IOP was independent of the duration of the SO endotamponade [41, 55].

HSOs are excellent tamponades for inferior pathology; however, they have some disadvantages when compared to conventional SOs. Cases must be carefully selected because HSO needs to be removed earlier due to a higher rate of inflammation, emulsification and high IOP.

Emulsification rates are reported between 4.3 and 42.4 % [56–61].

7.3.3.3 Prevention

Adequate filling is not only crucial for pressure control but also to have an adequate tamponade force and to reduce the risk of emulsification. Suturing sclerotomies, even when performing small-gauge vitrectomy, will prevent an underfill due to early leakage and subconjunctival SO droplets. Some experience is necessary to adjust the final pressure correctly. A difficult scenario is when, at the end of the surgery, a choroidal detachment appears. In these cases, it is mandatory to leave an adequate filling; however, we can still find high IOP due to overfilling if the choroidal detachment progresses in the early postoperative period as well as underfilling after its resolution.

Preventing emulsification can be achieved by reducing shear forces. With a good oil fill, there is minimal contact on the surface between the oil bubble and the aqueous humour; hence, there is a reduction in the movement of the oil/aqueous layer. Although, nowadays, encircling bands are not frequently combined with vitrectomy, we must remind the reader that geometrical alterations induced to the eyeball also contribute to reduce emulsification since there is also a reduction in the movement between these two fluids [62].

In order to prevent SO migration anteriorly in aphakic and pseudophakic patients, inferior peripheral iridectomy (PI) was introduced in 1985 by Ando [63]. The specific gravity of SO is 0.97; therefore, it floats superiorly. With an inferior iridectomy, the aqueous cycle will not be interrupted by the SO bubble, and the equilibrium between anterior and posterior chamber flows will prevent pupillary block and will keep the SO in the vitreous chamber.

To prevent acute angle-closure glaucoma, the iridectomy must be at least 150–200 μm in diameter [64]. The closure rate of PI varies between 11 and 32 %, and reopening with a YAG laser is not effective in a high percentage of cases [53]. Primary laser iridotomy also has a low rate of remaining patent long term. It is crucial to initially perform an adequate surgical iridectomy and to prevent closure by intense topical steroid therapy if fibrin is present in the postoperative period.

By correctly assessing the glaucoma risk before surgery and knowing that the population with myopia and proliferative diabetic disease are at a higher risk of having high IOP, we may be able to avoid this surgically induced complication or the exacerbation of a pre-existing condition [48].

The longer the endotamponade remains in the eye, the more likely the emulsifying process will happen. Removal before SO droplets get in contact with the trabecular meshwork will prevent damage to the normal aqueous outflow. This is much easier when the retinal situation is stable and SO can be safely removed. When SO is planned to remain long term in the eye, we must consider all the above points. If aphakia is planned, the whole capsular support must be removed, and an adequate iridectomy must be performed.

7.3.3.4 Medical Treatment

It is important to diagnose and appropriately treat inflammation with cycloplegics and corticosteroids when present, as this can be a mechanism for high IOP that is easily reversed. Medical therapy manages to successfully control glaucoma progression in 30–78 % of patients [39, 44]. Aqueous suppressants are the first line of treatment, and prostaglandins must be carefully used due to their proinflammatory effect and the risk for macular oedema.

7.3.3.5 Surgical Treatment

If IOP cannot be controlled with medical treatment, different surgical options are available.

As stated before, the earlier SO is removed, the lower the risk of such complications. Optimal control of pressure after removal of SO (ROSO) has been reported in many studies [41, 65]. This remains as the first step to control non-medical responsive glaucoma if the retinal situation is presumed to be stable enough to remain attached after SO removal and the trabecular meshwork is not closed by synechiae or rubeosis. In many cases, this may not be sufficient, and pressure will continue to be uncontrolled after ROSO [43, 44, 66]. Additional options available to lower the IOP include transcleral cyclophotocoagulation, which has a success rate between 44 and 82 % [53, 67, 68]. Classic trabeculectomy is not a first-line option due to the high failure rate because of conjunctiva scarring after vitreoretinal surgery. Budenz et al. found that combining ROSO with trabeculectomy increased the risk of postoperative hypotony. Glaucoma-draining devices are a potential option for unresponsive glaucoma. Al-Jazzaf et al. published a cumulative success rate of 86 % by 6 months and 76 % after 1 year of follow-up for an implanted Ahmed valve in the inferotemporal quadrant to avoid SO migration through the shunt [38].

7.3.4 Visual Loss After Removal of Silicone Oil

The aim of removing SO is to improve vision and reduce long-term complications. However, up to 27 % of the cases may experience mild to moderate vision loss, which can be due to retinal redetachment (6–25 %), hypotony (16 %), macular oedema (12 %) or epiretinal membrane. Severe visual loss is a rare complication after ROSO, and exact mechanisms that lead to this retinal dysfunction are still unclear.

Postoperatively, patients may notice visual loss that is due to a central scotoma. Relative afferent pupil defects can frequently be found, and electrophysiological studies show a wide range of alterations including dysfunction localized in the macula, RPE or widespread retinal alterations. Typically, fluorescein angiography and optical coherence tomography fail to show vascular or RPE alterations, epiretinal membranes and/or macular oedema.

The exact incidence is difficult to calculate. In a single report, Newsom et al. [69] estimated that severe visual loss occurred in 1 % of patients undergoing ROSO. A similar report was published by Herbert et al. [70], but these patients reported the same symptoms before ROSO.

The pathophysiological reason causing the retinal damage is unknown, and there are different hypotheses such as direct SO toxicity or the alteration of the electrolytic balance [71]. The preretinal aqueous layer, in the presence of the silicone bubble, may have higher concentration of ions, growth factors, interleukins and other proteins. Rapidly changing these environmental properties could explain visual loss after ROSO such that it causes irreversible cellular damage leading to apoptosis, which causes cell death without inflammation or oedema.

Unfortunately, there is no treatment for this severe visual deterioration; it is crucial to identify the underlying reasons that cause this phenomenon in order to establish better prevention methods.

7.3.5 Lens Opacity

Cataract formation is a frequent problem of vitreoretinal surgery, and more than 80 % of these patients will develop a cataract within 2 years [72, 73]. With the development of small-gauge vitrectomy, the percentage of cataract formation has diminished due to the reduction of the surgical time, fluidics and inflammation [74]. With the use of HSO, the rate of cataract formation becomes 100 % [56, 75].

Direct contact of SO with the posterior capsule, inflammatory activity localized within the aqueous anteriorly and emulsification among other factors contribute to early formation of the cataract.

7.3.6 Corneal Changes

Contact between SO and the endothelium damages the cells and causes necrosis, cell pleomorphism and, ultimately, corneal oedema, scarring

and band keratopathy. This last complication is the most common corneal change, which can be seen between 4.5 and 63 % of cases [76, 77]. After SO removal from the AC, corneal oedema can appear. This relates to the thinning and dehydration of the cornea while the SO bubble is over the endothelium, preventing aqueous contact [78]. When this isolation is removed, the damaged endothelium will not be capable of maintaining the correct corneal homeostasis. Histologically all corneal layers have been reported to be altered in SO keratopathy cases: retrocorneal membranes, stromal hypercellularity, superficial stromal calcification and vascularization, droplet deposition in the Bowman's membrane and endothelial stratus as well as in decreased endothelial cell density [78–80].

Avoiding migration of SO into the anterior chamber is crucial to prevent corneal damage. However, in patients with long-standing presence of SO, band keratopathy can develop as a consequence of subtle chronic inflammation, even if the SO tamponade is confined to the posterior chamber.

Conclusion

Silicone oil is a very useful aid for surgeons, and when used properly, most of the complications can be avoided by careful follow-up of the patients and adequate timing for SO removal. This should be done when the retinal situation is stable and as early and safely as possible.

In successful cases we recommend to remove the SO between 8 and 12 weeks and no more than 12 weeks if HSO has been used, although in these cases we tend to remove before the second month.

Surgeons and patients must be aware of the possible complications, which in the extreme can be vision threatening, for example, advanced glaucoma or severe visual loss after ROSO. The choice of tamponade must be taken on the basis of the surgical findings and patient characteristics, keeping in mind that C3F8 has a success rate comparable to SO when treating mild to moderate PVR retinal detachment cases.

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Management of Intraoperative Complications During Scleral Buckling Surgery

8

Francesco Boscia, Ermete Giacipoli, Giuseppe D'Amico Ricci, and Giancarlo Sborgia

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F. Boscia, MD (✉) E. Giacipoli • G.D. Ricci • G. Sborgia
Dipartimento di scienze chirurgiche, microchirugiche e mediche, Clinica Oculistica – University of Sassari, Sassari, Italy
e-mail: francescoboscia@hotmail.com

8.1 Introduction

Conventional scleral buckling is still thought to be the most efficacious and cost-effective primary procedure for the treatment of uncomplicated rhegmatogenous retinal detachment (RRD) [1, 2]. This relatively safe procedure can be associated with certain complications [3].

In this chapter, we will describe the principal complications during scleral buckle surgery and how to manage them intraoperatively [3].

8.2 Anesthesia

Periorbital anesthesia, with the migration of retina surgery to ambulatory surgery, is the most frequent choice for anesthesia.

The most common complications associated with this type of anesthesia are globe penetration or perforation, retrobulbar hemorrhage, diplopia secondary to muscle injury, optic neuropathy, and respiratory arrest for inadvertent brain stem anesthesia during dural sheath inoculation [4, 5]. In case of retrobulbar hemorrhage, control of hemodynamic is imperative, to preserve and minimize optic nerve injury, and in case of large retrobulbar hemorrhages, canthotomy may be necessary [6].

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8.3 Scleral Rupture

Each step of scleral buckling procedure can be affected by several complications. Some of these intraoperative complications are quite easy to manage and do not compromise the anatomical and functional outcome. Other complications can be potentially devastating for the visual recovery and challenging to manage.

At the beginning of the surgery, a 360° conjunctival peritomy is performed in order to expose the operative field. This maneuver is as essential as the placement of the buckle and the cryopexy.

A peritomy is combined with radial incision in the superonasal and inferotemporal quadrants to enlarge the circumference of the opened conjunctiva and to avoid tearing of the conjunctiva as this tissue is retracted to expose the sclera [7]. Isolating the entire muscles and avoiding splitting of the muscles belly are important to prevent diplopia, following scleral buckle. When the muscle hook is passed beneath the tendon insertion, it is important not to pass it posterior to the equator where it might damage the vortex veins. Also, when engaging the superior rectus tendon, the hook should be passed from the temporal toward the nasal directions to avoid engaging the superior oblique muscle, which extends in the opposite direction [7].

When the sclera is cleaned in all quadrants where retinal breaks are present and/or where scleral sutures will be placed, a careful inspection of the sclera for signs of marked scleral thinning (ectasia) is required in order to plan the most appropriate buckle approach [7]. Preexisting scleral pathology is a major risk factor for globe rupture during scleral buckling procedure [8]. Scleral thinning is more frequent in superotemporal quadrant and may appear as radial gray lines in the equatorial or pre-equatorial area or as a more substantial bulging of the sclera [7].

If a quadrant is too thin to accommodate a suture or a scleral tunnel, one may need to consider not anchoring the buckle in this quadrant, if the quadrant does not require a buckle to specifically support a break. Rarely, if the sclera is too tenuous, it could be necessary to abandon the scleral buckling procedure switching to vitrectomy [6]. Scleral rupture is a rare but serious complication of retinal detachment surgery. In the study by Tabandeh et al., reoperation after failed scleral buckling procedure and preexisting scleral pathology were identified as the main risk factors for this complication.

Inadvertent penetration of the sclera during scleral sutures placement has been reported to occur in about 5 % of the cases and is usually associated with high myopia and thin sclera [8]. In order to avoid this complication, it is important to adopt a proper suture technique: depress with the needle tip to obtain the initial depth; once the appropriate depth is obtained, flatten the needle to maintain this depth, and always be conscious of the needle depth throughout the entire pass. It is also important to avoid placing suture near vortex veins because of the risk of suprachoroidal hemorrhage.

When a scleral perforation occurs, this typically leads to drainage of the subretinal fluid, if the retina is detached, or to retinal perforations and hemorrhage, if the retina is attached. Under these circumstances, it is important to control the retina in order to evaluate the damage. The site of perforation should be treated with cryotherapy, and the scleral buckle position should be eventually modified in order to support the area of perforation. Perforation with inadvertent drainage of subretinal fluid is not necessarily a bad outcome, even if it can result in hypotony. Subsequent scleral sutures are more difficult to place in a hypotonous globe, and the risk of perforation increases [6]. In the eyes that have undergone previous RD surgery, scleral depression over the site of previously unnoticed suture penetration or cut-down sclerotomies or on an adjacent scleral explant may result in frank rupture.

Tissue glue may be used to facilitate the restoration of the globe. Scleral rupture can make the way to secondary intraoperative complication such as choroidal, subretinal, or vitreous hemorrhage and retinal incarceration [8].

Scleral buckle procedure outcome is directly dependent on the possibility to close and treat all the retinal breaks. A clear cornea and good pupil dilatation are necessary for adequate visualization of the fundus. If pupil constriction occurs during surgery because of sudden hypotony, a

normal intraocular pressure can be restored by injecting BSS or gas through the pars plana. Mild pupillary constriction unassociated with hypotony can be resolved by the injection of epinephrine in a concentration of 1:10,000 or less into the anterior chamber. If the corneal epithelium gets cloudy during surgery, this should be removed to permit optimal visualization [7].

Cryotherapy is the most common method used to treat retinal breaks [9, 10]. Each retinal break should be surrounded by a 1–2 mm zone of contiguous cryotherapy application, trying to avoid refreezing of the same area. Cryotherapy application is terminated when a visible effect is seen in the pigment epithelium or the overlying retina. However, if the pigment epithelium freezes but the overlying detached retina does not, the application should be stopped to avoid excessive choroidal damage [7].

There are two main complications linked to cryotherapy. The first occurs when the cryoprobe shaft creates a false indentation, preventing the surgeon from appreciating the correct position of the tip of the probe that lies more posteriorly than expected. This event may result in inadvertent cryopexy of the posterior pole. The second complication can occur if insufficient time is allowed for the cryoprobe to thaw before it is moved. If the probe is moved while it is still frozen, the choroidal vessel may rupture, resulting in a subretinal hemorrhage or scleral avulsion with a consecutive scleral defect. In this case, if the sclera is healthy and the defect is small, a simple mattress suture can be applied. If the defect is large, or the sclera is ectasic, a buckle, with or without glue, can be sutured into place. Alternatively, donor sclera or pericardial patch graft can be sutured over the defect.

8.4 Subretinal Fluid Drainage Complications

The drainage of subretinal fluid remains the step of the scleral buckling with the greatest potential for complications. The decision to drain subretinal fluid at the time of scleral buckling remains controversial. In a prospective randomized trial, Hilton noted that equally successful anatomical and functional results can be obtained either with drainage or non-drainage technique [11], even if there was a greater incidence of complications in the drainage group. On the other hand, in all the situations in which the buckle element alone is not able to create an appropriate indentation to close the retinal break, subretinal fluid drainage is necessary.

Careful selection of the drainage site will help to minimize potential complications. There are many factors to consider in selecting the location of drainage, including the distribution of subretinal fluid and the configuration of the detachment, the vitreoretinal and epiretinal membrane tractions, the location of retinal breaks, the configuration of the scleral buckle, and the choroidal vascularity. A good strategy to minimize retinal damage is to perform the drainage where the retina is the most highly detached (abundant subretinal fluid) and far from the retinal break.

In their study, Wilkinson and Regan reported that the main complications of drainage were loss of formed vitreous, vitreous hemorrhage, choroidal hemorrhage, retinal incarceration, and subretinal hemorrhage.

During the drainage, a cotton tip applicator is placed on the eye between the conjunctiva and the sclera to maintain normal IOP and to guarantee a complete outflow of the fluid. Bleeding from the drainage site can indicate possible choroidal, subretinal, or vitreous hemorrhage. A premature cessation of subretinal fluid drainage can be an indicator of possible retinal or vitreous incarcerations [12]. If retinal incarceration occurs during the drainage procedure, cryotherapy of the site and support with a scleral buckle are necessary [6].

Patterson and Ryan observed that complication rates of drainage of subretinal fluid can be reduced or detected earlier using a variant technique involving continuous intraocular monitoring during the drainage. This technique allows imminent complications to be detected before significant damage occurs, giving the possibility to the surgeon to get a better control over the drainage process. During drainage, if vitreous gel is observed to pass through the tear, the cotton-tipped applicator is rotated with pressure over the tear externally while verifying that the tear has

been closed internally. If subretinal bleeding is noted, this can be arrested via external tamponade using the cotton-tipped applicator over the drainage site. The fluttering of retina during the process of drainage is useful as an indicator of an impeded drainage. The absence of retinal fluttering or the presence of retinal dimpling can indicate imminent retinal incarceration as the retina tends to dimple as it nears the choroidotomy site. If such an event is observed, the drainage site is massaged with cotton-tipped applicator in a rolling fashion, which will release the dimpled retina, preventing incarceration. Flattening of the retina against the RPE is observed as the residual SRF drains [12].

8.5 Accidental Drainage of Subretinal Fluid

An inadvertent scleral perforation with the release of subretinal fluid can occur during placement of scleral buckling sutures. This event can be problematic for the surgeon also in cases where subretinal fluid drainage has been planned. The management of accidental subretinal fluid drainage changes according to whether or not subretinal fluid drainage was intended. If the drainage was planned, the accidental drainage site is allowed to drain spontaneously after the removal of the sutures. If the drainage was not planned, offending sutures are quickly removed, and hypotony prevention is made by rapidly placing a stitch more widely so that subsequent tightening would seal off the drainage site. In few cases an intravitreal injection of air could be necessary. The biggest secondary complications resulting from an inadvertent drainage of subretinal fluid with consequent hypotony is choroidal hemorrhage [13].

8.6 Choroidal Hemorrhage

Choroidal detachment is the most common complication of scleral buckling procedures, occurring in 23–44 % of cases. It can be classified as serous, serohemorrhagic, or hemorrhagic [14]. It usually occurs in the first days after surgery, but sometimes it can be observed during or immediately after surgery. Verma et al. reported on 25 consecutive cases of choroidal detachment following retinal detachment surgery out of a total of 510 cases undertaken. In this study choroidal detachment at the end of surgery was noted in 12 % of cases. Postoperatively, choroidal detachment was observed on day 1 in 8 % and between the third and fourth day in 48 %. The remaining 32 % of patients developed this complication between postoperative days 4 and 5 [15]. The precise pathogenesis is unknown. Nevertheless, it is usually self-limited and resolves spontaneously in approximately 2 weeks. In some cases it can reduce visual function [16]. Many preoperative and intraoperative conditions can play a role in this complication. Among the preoperative conditions, myopia, advanced age (aging changes the integrity of the choroidal vasculature), and systemic conditions (history of hypertension) were considered risk factors for the occurrence of choroidal detachment. Among the intraoperative conditions that can bring to a choroidal detachment, the damage to a vortex vein and the fluctuation of IOP (hypotony) during surgery seem to be the most remarkable. In one reported study, this complication was seen to affect 22 % of patients with no evidence of vortex vein damage or obstruction. The incidence increases to 27.7 % when one and two vortex veins respectively were compromised. Another intraoperative predisposing factor is the hypotony that can be generated during the scleral buckling procedure in particular when subretinal drainage is performed [15]. In this situation, an increased intramural pressure in the choroidal vascular plexus resulting from imbalance between local blood pressure and low intraocular pressure is supposed to be the first step leading to the development of choroidal detachment [16]. The incidence of choroidal detachment in patients in whom no drainage of subretinal fluid has been undertaken is inferior (5–7 %) than the incidence in case of subretinal fluid drainage. Other predisposing factors are the extension of the buckle (Verma et al.: incidence of 10 % in segmental buckle; incidence of 28 % in encircling element in addition to the buckle) [15].

The surgeon who performs retinal detachment surgery must be aware of the delicate balance existing between choroidal hemodynamic and intraocular pressure. Great care must be taken during critical maneuvers such as scleral sutures and drainage of subretinal fluid in order not to create accidental perforations with consecutive drastic decrease of the IOP. Moreover, every time the scleral surface is approached, maximum care must be taken of the vortex veins.

Management of choroidal detachment can be both medical and surgical, depending on the severity of the detachment.

The intraocular pressure must be settled to normal range. Immediately after surgery the patient has to be administered topical and systemic steroids and diuretic drugs (Acetazolamide) that can lead to a rapid absorption of suprachoroidal fluid [16].

In all the cases in which the choroidal detachment is complicated with retinal detachment, central choroidal apposition (CCA), retina or vitreous incarceration into the wound, a persistent flat anterior chamber, extreme pain, or uncontrolled elevated intraocular pressure, a surgical drainage of suprachoroidal hemorrhage is advocated [17].

Surgical management of suprachoroidal hemorrhage includes either primary drainage alone, primary and secondary drainage, or secondary drainage alone.

Primary drainage indications include: a rapidly expanding intraoperative hemorrhage or the inability to reposit intraocular contents. It is performed through a posterior sclerostomy at the time of wound closure.

Secondary drainage is performed through a posterior sclerostomy, under a constantly maintained limbal fluid line infusion. This delayed approach is attempted only after echographic evidence of suprachoroidal hemorrhage liquefaction.

Retinal detachment and retinal or vitreous incarceration can be managed either with pars plana vitrectomy with scleral buckle placement or with pars plana vitrectomy and silicon oil tamponade without scleral buckling.

Even if a surgical drainage of suprachoroidal hemorrhage is deeply recommended in the situations listed above, the visual prognosis after this surgery remains poor. In a study by William et al., only 35 % of the operated eyes maintained a visual acuity equal or superior to 5/200. The factors that were associated with a worse prognosis included retinal incarceration and retinal detachment at presentation [17].

8.7 Subretinal Hemorrhage

Subretinal hemorrhage is a potentially serious complication of scleral buckling surgery that can occur during subretinal fluid drainage, following scleral depression, or as a result of a deep suture pass [18].

The visual outcome in patients with subretinal hemorrhage clearly depends on the retinal area under which the blood collects.

Small, self-limiting subretinal hemorrhages, mainly in the nasal retina, not involving the macula, usually do not have serious consequences on the anatomical and visual outcome. Draining subretinal fluid in a nasal quadrant is advantageous because, if the procedure is complicated by subretinal hemorrhage, the chance of blood accumulating under the macula is reduced [7].

Submacular blood, if not properly drained, can lead to a severe visual outcome, especially with thick hemorrhages. It has been postulated that subretinal blood damages the photoreceptors in several ways: toxic effect induced by iron, barrier effect played by the coated blood between photoreceptor and pigmented retinal epithelium, and/or mechanical actions induced by coated blood. Furthermore, subretinal blood can interfere with retinal reattachment and become a PVR promoter [18].

A common surgical approach for large subretinal hemorrhages treatment, resulting from a complication of scleral buckling surgery, is pars plana vitrectomy with blood displacement by using perfluorocarbon liquid and its drainage into the vitreous cavity through a retinal break or a drainage retinotomy [8]. Subretinal tissue plasminogen activator (TPA) injection can be adjunct in this treatment, especially if a substantial clot forms.

In a case report by Ramin et al., a 46-year-old patient with a submacular hemorrhage, developed during a scleral buckle procedure, was treated by injecting 1 ml of air into the vitreous cavity under visualization with indirect ophthalmoscopy and positioning the patient face down for 3 days in order to displace the blood beneath the macula. The visual and anatomical outcomes in this case were both good. One month after surgery, the retina remained attached and the macula showed no evidence of subretinal hemorrhage. BCVA was 20/60 [18]. This approach with some variants is reported also in other papers in which usually a gas bubble is injected via pars plana in the vitreous cavity with or without intravitreal TPA [19–12].

8.8 Scleral Buckling When No Break Is Found

The inability to find retinal break in a rhegmatogenous retinal detachment has been reported to be associated with a poor prognosis compared to cases in which the break was identified [23]. Despite clear visualization of the fundus, retinal breaks can't be found in 2.2–4 % of phakic eyes with retinal detachment and in 7–16 % and 5–22.5 % in aphakic and pseudophakic, respectively [24]. Many factors can interfere with identifications of retinal breaks: poor mydriasis, cortical remnants, capsular opacifications, glare of the intraocular lens implant, corneal opacifications, and small breaks especially in the anterior portion of the peripheral retina. Pars plana vitrectomy is considered to be the best technique to manage such cases, even if some studies conclude that pars plana vitrectomy does not allow better detection of the break that was missed preoperatively [25]. Other studies have shown that the management of undetected retinal breaks by using circumferential buckling and broad application of cryopexy achieved a primary success rate ranging from 53 to 85 % [24]. The rationale of encirclement is to support unseen peripheral retinal breaks by releasing vitreous tractions. Salicone et al. compared the anatomical and functional results of two groups of patients with rhegmatogenous retinal detachment and undetected breaks who underwent two different surgical approaches. The first group (combined group, 18 eyes) underwent a combined approach consisting of scleral buckling and pars plana vitrectomy. The second group (26 eyes) was treated only with a scleral buckling procedure (encircling). After a mean follow-up of 8.3 month, there was no statically significant difference between the two techniques in terms of retinal reattachment rate, visual functions (group 1 mean BCVA of 1.07 logMAR units at last visit, group 2 mean BCVA 1.26 logMAR units), and complications rate [24]. These results show that the scleral buckling procedure alone is as effective as combined pars plana vitrectomy with encircling band in the management of retinal detachment with undetected retinal breaks.

Usually in these cases, a 360° scleral buckling procedure is needed. Cryopexy should be applied on all suspicious areas, also because, as described by Griffit et al., the use of exploratory cryotherapy can identify a retinal break [26]. Subretinal fluid drainage has to be performed if the buckling element alone is not able to create a proper indentation.

Adopting this technique it is possible to decrease all the peripheral vitreous tractions, providing an effective support to the retina with long-lasting anatomical and functional results.

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9 Management of Intraoperative and Postoperative Complications During Vitrectomy for Retinal Detachment

Cesare Mariotti, Michele Nicolai, and Andrea Saitta

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C. Mariotti (✉) • A. Saitta
Department of Ophthalmology, Università Politecnica Delle Marche, Ancona, Italy
e-mail: mariottiocul@gmail.com; andrea@dottorsaitta.it

M. Nicolai, MD
Department of Ophthalmology, Università Politecnica Delle Marche, Ancona, Italy
e-mail: michelle.nicolai@hotmail.it

9.1 Introduction

Recent evolution in vitreoretinal procedures has led to a significant reduction in intraoperative and postoperative complications.

Patients who undergo vitrectomy with minimally invasive technique do not experience peritomy-related postoperative conjunctival scarring. Preserving the conjunctiva reduces the postoperative discomfort and offers the chance of an easier management of one of the most serious complications after pars plana vitrectomy, that is, secondary glaucoma.

9.2 Intraoperative Complications

9.2.1 Sclerotomy-Related Complications

Sclerotomies are normally placed 3.5–4 mm posterior to the limbus in the phakic eyes and 3 mm in the pseudophakic or aphakic eyes. The infusion cannula is normally positioned in the inferotemporal quadrant, and superotemporal and superonasal sclerotomies are conducted near the 10 and 2 o'clock meridians. The risk of hemorrhage from the sclerotomy site is very low if the trocar is placed in the right position. The bleeding can be subconjunctival, intravitreal, or in the anterior chamber. In the event of a big subconjunctival

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bleeding, it is advisable to stop the hemorrhage with endodiathermy, suture the sclerotomy, and place the trocar in a different site. In the case of an anterior chamber bleeding, the blood should be promptly removed with a syringe to improve the view of the back of the eye.

Displacing the conjunctiva is very important for a correct wound construction. The aim of this procedure is to misalign the hole in the conjunctiva and the one in the sclera to minimize the risk of vitreous wick. Flatten the sclera while inserting the trocar, and making an angled incision increases tunnel length and helps wound closure [1].

One of the milestones in vitreoretinal surgery is that it is fundamental to check the infusion line before starting the vitrectomy in order to be sure that the trocar is correctly inserted into the vitreous chamber and fully patent. In bullous retinal detachments, the risk of a subretinal positioning of the infusion cannula and consequent exudative retinal detachment is higher. To avoid this complication the surgeon should avoid areas of bullous detachment to insert the infusion cannula and make sure that the trocar is in the vitreous chamber before opening the infusion line.

As soon as the surgeon starts vitrectomy, it is very important to free the trocar from vitreous strands that may prevent BSS flow into the vitreous chamber. To achieve this sometimes it is necessary to perform a scleral depression around the site of the infusion line in order to improve the trocar visualization and to facilitate vitreous removal. Particular attention is necessary on performing a complete shaving of the vitreous from the internal sclerotomy site so that vitreous is meticulously removed around the ports. This is also important to avoid breakage of the air flux during air/fluid exchange as this can cause the air to be divided in small bubbles that can significantly decrease retinal visualization.

Spontaneous dislocation of the cannula can occur during the exchange of instruments between the ports, and also, more importantly, the cannula attached to the infusion line can dislocate during scleral depression causing intraoperative loss of volume. Repositioning of the cannula should repressurize the eye.

Prolapse of a vitreous wick through the sclerotomy site may create a potentially open conduit through the conjunctival and scleral wound that may facilitate entry of bacteria into the eye [2]. Once again, more complete vitrectomy at or near the sclerotomy sites decreases this risk. Also, the use of air tamponade at the conclusion of surgery may act as both a barrier to bacterial inoculation and a way to prevent hypotony.

If the infusion line trocar is incorrectly positioned in the subretinal space, the BSS flow can cause a big exudative retinal detachment. If this occurs, the best way to proceed is inserting an extra trocar to connect the infusion line without removing the trocar which was inadvertently positioned in the subretinal space so that the BSS flow can increase the IOP in the vitreous chamber and displace the subretinal fluid that will be drained by the trocar originally inserted in the wrong position. Once the subretinal fluid has been drained, the trocar can be removed and the sclerotomy closed. To prevent this complication, it is advisable to avoid areas of bullous detachment when placing the infusion line.

Displacing the trocar while removing the instruments from the eye can result in conjunctival chemosis or entrapment of air, depending on what is being infused. If this happens, it is advisable to dissect the conjunctiva to drain the fluid and then reposition the trocar in a different site.

Finally valved trocars are really helpful to minimize the risk of hypotony and consequent bleeding, especially in diabetic patients, during the procedure.

9.2.2 Corneal Complications

During the surgery, increased intraocular pressure during the placement of trocar cannulas can put undue stress on prior corneal or limbal wounds such as in eyes that have had sutureless cataract surgery or recent corneal transplants. Suture closure of recent corneal and scleral wounds may be desirable, especially if the surgeon is planning to indent the peripheral retina to achieve a complete peripheral vitrectomy. Scraping of an unclear corneal epithelium is recommended to increase the quality of vision.

9.2.3 Hyphema

Bleeding in the AC most commonly occurs in patient with iris rubeosis when the IOP is slow during the procedure. Avoiding hypotony is therefore fundamental in patients at risk but; if this happens, the best way to proceed is performing an AC washout with BSS through a paracentesis. A subsequent injection of viscoelastic in the AC may be a good option to prevent further bleeding.

9.3 Vitrectomy Complications

As a consequence of a vitrectomy, two types of iatrogenic peripheral retinal breaks have been described: those associated with entry sites and those occurring elsewhere in the retina [3]. Entry site breaks are believed to be caused by traction on the vitreous base, either as a result of the insertion and removal of instruments during the surgery or as a complication of vitreous becoming incarcerated in a sclerotomy [4]. Retinal breaks elsewhere developing during vitrectomy generally result from traction to the retina by the vitreous cutter or have been described as a result of a posterior vitreous detachment induced surgically. It has been shown that, in small-gauge vitrectomy, most of the iatrogenic retinal breaks occur at sites other than the sclerotomy, with a low incidence of entry site breaks [5]. These observations confirm that, in small-gauge vitrectomy, breaks arise not only from traction at entry sites and intraocular manipulation but also from the process of separation of the vitreous from the peripheral retina during vitrectomy. The frequency of iatrogenic retinal breaks during pars plana vitrectomy has been reported to range from 0 to 24 % with post-PPV retinal detachment occurring in 0–15.8 % [3, 6–8].

In a recent study the frequency of iatrogenic breaks in 302 eyes with tractional retinal detachment after performing pars plana vitrectomy was 32.45 % [9]. Surgical-induced posterior vitreous detachment can result in the formation of small peripapillary retinal hemorrhages as the area around the optic nerve is where the vitreoretinal adherence is stronger. These hemorrhages normally resolve spontaneously. If a small break is identified during this procedure, it is advisable to mark it with endodiathermy to make it clearly visible and facilitate the treatment with argon laser at the end of the procedure.

Performing the peripheral vitrectomy under air may be an efficient way to reduce the risk of iatrogenic breaks. The advantages offered by the air are better intraoperative visualization and safer removal of the vitreous base; both aspects are due to the physical properties of the air inside the vitreous cavity [10]. The air–vitreous interface facilitates visualization of vitreous base and allows an easier shaving of residual vitreous; furthermore, the air stabilizes the retina because of the inherent spring-like properties of a compressible gas, against the aspiration force of the vitreous cutter, thereby reducing the possibility of iatrogenic retinal breaks.

In phakic eyes the surgeon can inadvertently touch the lens during vitrectomy. This normally does not cause a decreased quality of vision during the procedure but often results in secondary cataract formation. To avoid this inconvenience, the surgeon should always vitrectomize the vitreous base in the area opposite to the sclerotomy site. All patients should have an IOL calculation prior to surgery so that a vitreoretinal procedure can be converted to a combined surgery at any time.

In pseudophakic patients, vitrectomy can induce IOL dislocation in the vitreous chamber. If the dislocation is complete, the lens should be removed and a secondary AC lens implant should be postponed to a subsequent surgery.

9.3.1 Fluidic Dynamics-Related Complications

An intimate understanding of the fluidic dynamics allows to avoid mistake during vitreoretinal surgery. Fluid–air exchange is very important to drain subretinal fluid.

Although visualization of the retina can be improved with an air-filled eye, in a pseudophakic eye with a disrupted posterior capsule, air can fog the intraocular lens and compromise the view [11]. It can be possible to use humidified air, coat

the posterior surface of the intraocular lens with viscoelastic, or wipe the posterior surface of the intraocular lens with a soft-tipped cannula [12, 13]. In addition, migration of air into the anterior chamber via zonular dialysis in pseudophakic and phakic eyes can severely compromise visualization of the posterior segment. If the air repeatedly reaches the anterior segment during the procedure, the surgeon should fill the AC with viscoelastic.

It is advisable to administer perfluorocarbon liquid (PFCL) into the eye with a dual bore cannula that allows pressure release via passive egress of the intraocular fluid displaced by PFCL. If this cannula is not available, the surgeon should be very cautious when administering the PFCL to avoid rise in IOP during this procedure. Using nonvalved trocars, the surgeon may encounter formation of PFCL microbubbles due to changes in the intraocular fluidics that occur immediately after instrument removal. This is of particular concern in cases with large breaks or retinectomy and when the retinal break is posterior (such as in high myopia with posterior pole atrophy) in which subretinal PFCL migration may happen easily. In a patient at risk any membrane causing retinal stiffness should be carefully removed before PFCL injection as a rigid retina is more prone to cause the tamponade agent to reach the subretinal space. If this complication occurs, PFCL should be promptly aspirated from the retinal break due to the potential for toxic effects of the liquid on the retina. Subretinal migration of small PFCL bubbles can be subtle and can sometimes only be noticed in the postoperative period. In such cases early intervention appears to be warranted only if central vision remains at risk with subfoveally located droplets.

Subretinal PFCL is a rare but serious complication associated with retinal detachment repair primarily due to the potential for toxic effects of the liquid on various structures of the eye. While it is optimal to detect and remove subretinal PFCL intraoperatively, retained PFCL may be missed in 1–11 % of cases and not detected until follow-up visits [14]. In such cases, early intervention appears to be warranted particularly if central vision remains at risk with subfoveally located droplets. Restoration of the foveal contour and attenuation of scotoma size as indicated by optical coherence tomography and microperimetry imaging suggest a good prognosis based on the limited number of case reports reviewed. Prognosis of retained PFCL depends on the location, size, and duration of its contact with retinal structures [15].

Although several techniques for the removal of subfoveal PFCL bubbles have been described [15–19], no standard treatment method has been established. Attempted pneumodisplacement by injecting intravitreal gas has been unsuccessful [15]. Direct surgical aspiration via a juxtafoveal retinotomy site adjacent to the retained PFCL bubble has been attempted with variable results [16–18]. Recently it has been proposed surgical removal of the subfoveal PFCL through a therapeutic macular hole and gas tamponade [19].

9.3.2 Laser Retinopexy

Endolaser retinopexy is essential for retinal detachment cases. Subretinal fluid should first be drained with air-filled vitreous cavity.

High potency of endolaser can cause retinal and choroidal hemorrhages or retinal holes. Rarely it is necessary to treat these hemorrhages. Barrage laser around iatrogenic hole must be performed.

9.4 Early Postoperative Complications

9.4.1 Hypotony

Reports have shown the prevalence of up to 20 % of postsurgical hypotony using 25 gauge in earlier series [20]. In most cases IOP values normalized within a few days with no residual problems. The only factor that has been found to be significant in the formation of hypotony with sutureless vitrectomy has been young age of the patient [21]. Better wound construction has now

minimized this problem [22]. Postoperative endophthalmitis was initially suspected to occur more frequently after sutureless vitrectomies. Some authors have proposed that there is a correlation between relative hypotony at the conclusion of surgery and the influx of bacteria through sclerotomy sites, increasing the risk of endophthalmitis [23, 24]. More recently published large retrospective studies do not indicate that sutureless small-gauge vitrectomy (23 and 25 gauge) is associated with higher rates of endophthalmitis compared with standard vitrectomy (20 gauge) [25].

9.4.2 Corneal Complications

Silicone oil is an important tamponade in the treatment of retinal detachment, and it should be removed once the purpose of tamponade has been achieved in order to minimize its long-term complication.

Eyes with prolonged silicone oil tamponade invariably develop corneal abnormalities in the form of diffuse bullous corneal edema or calcific band keratopathy.

Band keratopathy is more common in younger patients, and it may occur when the silicone oil comes in contact with the corneal endothelium either as an intact large silicone oil bubble or as emulsified droplets [26]. The keratopathy is thought to result from pH changes caused by reduced flow across the cornea [27]. The higher viscosity (5,000 centistoke) silicone oil suppressed cell cycling significantly more than the lower viscosity (1,000 centistoke) silicone oil [28].

Anyway the development of keratopathies has been greatly reduced by the introduction of ando iridectomy [29], and this complication is now largely confined to eyes with severe trauma, hypotony, aniridia, or aphakia. Ando iridectomy consists of a 6 o'clock iridectomy preventing silicone oil from entering the anterior chamber. By cohesive forces the silicone oil bubble tends to take on a smooth spherical form within the aqueous-filled posterior segment of the vitrectomized aphakic eye. Silicone oil will not enter the anterior chamber as long as it does not create a pupillary block. With an existing pupillary block, the aqueous will accumulate behind the iris diaphragm at the lowest part of the posterior segment. During waking hours, this is at the 6 o'clock position behind the iris. Pressure building up by aqueous production forces silicone oil through the pupil and results in an oil-filled anterior chamber. An iridectomy at the 6 o'clock position prevents a pupillary block and ensures passage of aqueous toward the chamber angle. An iridectomy at the 12 o'clock position is less likely to solve the problem because the silicone oil bubble is directly behind the iris and is floating against the diaphragm in the upper part of the eye.

Band keratopathy is managed with chemical chelation using a 1–2 % solution of ethylenediaminetetraacetic acid (EDTA) (0.37 mol) in water or saline, following mechanical removal of the epithelium using a spatula or the edge of a No. 15 blade [30, 31]. Band keratopathy has been also treated successfully using excimer laser phototherapeutic keratectomy in order to clear the visual axis and improve vision [32, 33]. The amniotic membrane has been used after the primary surgical removal of band keratopathy to quickly restore a stable ocular surface [34].

Severe keratopathy needs keratoplasty if vision is to be improved. This may be done before, during, or after silicone oil has been removed from the eye.

9.4.3 Gas-Induced Elevated Intraocular Pressure

Compared to air, intraocular gases have the advantage of providing a prolonged tamponade of retinal breaks in order to promote a firm chorioretinal adhesion, but they can cause a rise in intraocular pressure that, although is often transient, can be severe [35]. An expansible gas injected into the vitreous cavity may cause anterior displacement of the iris–lens diaphragm and secondary angle closure. Equilibrated gases diluted with air in concentrations of 20 % for SF6, 16 % for C2F6, and 14 % for C3F8 may

provide a safe tamponade with a lower incidence of IOP elevation. SF6 more frequently causes ocular hypertension during within 48 h after the surgery, while C3F8 is less commonly associated with a rise in pressure but if this happens it normally lasts longer [36].

Face-down posture is important not only for anatomical success but also to avoid forward displacement of the iris–lens diaphragm. Changes in atmospheric pressure can cause intraocular gas expansion and result in an acute IOP increase.

If gas overfill is suspected in case of a severe elevation of IOP and compromised ocular perfusion, aspiration of a quantity of the intraocular gas by aspiration via pars plana with a 30G needle should be performed. Anterior chamber paracentesis should be avoided because of the risk of lens, IOL, or iris dislocation.

9.4.4 PDMS-Induced Elevated Intraocular Pressure

Postoperative increase of IOP when PDMS is used as tamponade can occur at any time ranging from mild and transient to severe and permanent, resulting occasionally in refractory glaucoma. In recent studies, this incidence rate has been found to be lower than previously reported, probably due to improvement of surgical techniques and refinement of surgical materials. In the prospective Silicone Oil Study Group, the incidence of chronic IOP elevation in 241 eyes with PVR managed by pars plana vitrectomy and silicone oil injection (PPVSOI) was found in 8 % of patients [37]. The incidence of secondary glaucoma with intraocular silicone oil use ranges from 2.2 % in 6 months to 56 % in 8 months, so therefore, the longer that the oil is present in the eye, the more likely it is to cause secondary glaucoma. The rise in intraocular pressure when PDMS is used as tamponating agent can be the result of several problems, such as inflammation, overfilling, presence of a PDMS bubble in the AC, or presence of PDMS emulsification in AC. Ando introduced the concept of inferior peripheral iridectomy in aphakic and pseudophakic eyes to prevent forward migration of silicone oil and reduce the incidence of pupillary block glaucoma [38]. Failure to perform an adequate inferior peripheral iridectomy increases the risk of developing pupillary block.

Treatment of ocular hypertension is generally medical and can include topical or systemic aqueous humor suppressants. Prostaglandin analogues are less frequently used as first-line therapy postoperatively due to concerns about inducing intraocular inflammation and cystoid macular edema [39].

SO removal does not necessarily provide IOP control. The prolonged contact of SO with the trabecular meshwork may cause structural changes due to infiltration of oil microbubbles, resulting in sustained IOP rise, despite SO removal. These SO droplets can often be detected only by gonioscopy. Performing this examination is therefore very important in patients with ocular hypertension after vitreoretinal surgery. Thus, the surgical management of these patients should be customized according to gonioscopic findings, IOP level, onset and duration of IOP elevation, status of posterior segment or visual function, and prognosis. The underlying mechanism may often be multifactorial in nature. Patients in whom uncontrolled IOP develops may benefit from aggressive medical and/or surgical treatment with silicone oil removal, glaucoma implants, or cyclodestructive procedures. Conventional filtration surgery has a limited role and success rate in the management of glaucoma after pars plana vitrectomy and silicone oil injection. Ahmed glaucoma valve implantation with inferior placement to reduce the chance of silicone oil from flowing into the tube.

9.5 Late Postoperative Complications

9.5.1 Glaucoma

Despite the encouraging anatomical and visual results obtained from intravitreal silicone oil injection in the management of complicated

retinal detachment, glaucoma can be a common adverse occurrence. Tranos et al. [40] identified multiple vitreoretinal surgeries and diabetes to be risk factors for secondary glaucoma after PPVSOI.

9.5.2 Proliferative Vitreoretinopathy (PVR)

Proliferative vitreoretinopathy (PVR) is a process of cellular proliferation, caused by the healing process of glial and retinal pigment epithelial (RPE) cells that moved to the vitreous chamber following a retinal detachment and proliferate and form membranes on the retinal surface in the subretinal space. These proliferations contract and cause shortening of the retina and cause retinal breaks and can lead to persistent or progressive RD. Risk factors for PVR formation in RD include numerous and/or large retinal breaks, chronic RD, trauma, previous intraocular surgery, vitreous hemorrhage, and uveitis. Patient age is also a factor as in younger patients, the proliferative healing response is more aggressive. The treatment consists in relieving all traction, both from epiretinal membranes and from subretinal fibrosis. Bimanual approach is becoming less common with the improvements in surgical techniques. Better visualization with wide-angle systems, small caliber instrumentation, and high cut ratio probes allow to solve most of the traction without direct manipulation of the retina with two forceps. With the smaller gauge equipment, it is easier to have access to spaces under the retina or in the midst of epiretinal scar tissue using the vitreous cutter to delaminate the retina or perform a retinotomy, procedures that required the use of scissors a few years ago. When a bimanual approach is necessary, the new 25–27G chandeliers usually provide an optimal amount of light despite the smaller caliber. In these situations, Eckardt and crocodile forceps can delaminate any membrane without the need of scissors.

9.5.3 Macular Hole

Macular holes developing after retinal detachment repair are a rare complication (less than 1 %) [41–43]. Its physiopathological mechanisms are not well known. Conventional macular hole surgery including pars plana vitrectomy, inconstant internal limiting membrane delamination, and long-acting gas tamponade seems to achieve to macular reattachment (89 %) [25]. The visual outcome seems conditioned by the macular status noticed during the retinal detachment.

9.5.4 Retinal Folds

Persistent foveal detachment, distortion, and disruption of outer retinal layers (ORFs) and macular folds are common findings following successful surgery for retinal detachment [44]. ORFs tend to resolve spontaneously within a few months from operation leaving no or subtle abnormalities at the level of the outer retinal layers. The following factors might be involved in ORFs pathogenesis: structural changes occurring in the detached retina, residual pockets of subretinal fluid after retinal reattachment, intravitreal gas, unintentional retinal translocation, and intraoperative or perioperative hypotony [44].

ORFs must be differentiated from full-thickness retinal folds, which may become fixed, may require further surgical intervention [45, 46], and are associated with apoptosis and thinning of the photoreceptor layer within the fold [47]. ORFs should also be differentiated from residual subretinal fluid, which can take years to be reabsorbed [48, 49], and from retinal vessel printings, which do not substantially change during follow-up [50].

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Microincision Vitrectomy Surgery in Infectious Endophthalmitis

10

Mohamed Haji and Flavio A. Rezende

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M. Haji
Department of Ophthalmology,
University of Montreal, Montreal, QC, Canada

Department of Ophthalmology,
King AbdulAziz University, Jeddah, Saudi Arabia

F.A. Rezende (✉)
Department of Ophthalmology,
Pontificia Universidade Catolica,
Rio de Janeiro, Brazil

Department of Ophthalmology,
University of Montreal, Montreal, QC, Canada
e-mail: frezendef@hotmail.com

10.1 Introduction

Infectious endophthalmitis is one of the most feared ocular diseases that results from an inflammatory reaction toward microorganisms (or their toxins) that gained access to the sterile intraocular environment [1]. Based on the source of the causative agent and time of onset, it can be divided into endogenous or exogenous and early or chronic, respectively [1, 2]. The severity of the inflammatory reaction depends on the virulence and load of the infecting agent and the patient's immune status. It can affect any intraocular structure and, in extreme cases, may cause panophthalmitis, orbital cellulitis, cavernous sinus thrombosis, or even death [1].

Endophthalmitis is divided clinically into endogenous, when the cause is a distant focus of infection and reaches the eye hematogenously, or exogenous, when the cause is an ocular surgery, a perforated corneal ulcer or hydrops, or an open-globe injury. Based on the time of presentation, it is divided into acute, within 6 weeks of the inciting event, or delayed postoperative (post-op)/chronic endophthalmitis, up to years after the event [2]. Exogenous endophthalmitis is more frequently encountered than the endogenous type (4–15 %) due to the ever-increasing number of performed ocular surgeries worldwide [3–5]. Briefly, the source of endogenous endophthalmitis can be an infectious endocarditis, infected central line, urinary tract infection, liver abscess, intravenous drugs, or immunosuppression.

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A systemic workup is usually necessary, and treatment includes intravenous and intravitreal antibiotics with or without vitrectomy. The majority of cases are caused by *Candida* sp., *Aspergillus* sp., and *Klebsiella* in cases of liver abscesses [3–5]. The outcomes of this clinical entity are usually poor.

Exogenous post-op endophthalmitis can occur after phacoemulsification (phaco) with intraocular lens (IOL) implantation, secondary IOL implantation, glaucoma surgery (mainly trabeculectomy with antimetabolites), intravitreal injections, Boston keratoprosthesis (KPro), or vitrectomy, but it can occur after any surgical or traumatic penetration of the eye.

As exogenous endophthalmitis post-op is more common, this chapter will address this type and its surgical management using MIVS and the safety and efficacy of MIVS compared to the traditional 20-gauge vitrectomy and will discuss briefly the use of endoscopy-guided MIVS to treat this condition.

A brief review of acute and chronic post-cataract/secondary IOL surgery; bleb-associated, post-intravitreal injection; post-KPro; and post-vitrectomy endophthalmitis will be provided.

10.2 Postoperative Endophthalmitis

10.2.1 Acute Post-phaco and IOL/Secondary IOL Endophthalmitis

Acute post-op endophthalmitis usually presents with sudden loss of visual acuity (VA), increasing ocular pain, decreased or diminished red reflex, relative afferent pupillary defect, lid edema, ciliary and conjunctival injection, corneal edema and/or infiltrates, wound dehiscence, loose sutures, anterior chamber reaction, hypopyon, fibrin membrane formation, pigment deposition on the IOL, vitritis with vitreous opacities or membranes, intraretinal hemorrhages, periphlebitis, and/or retinitis with or without retinal necrosis, but the retina is usually difficult to visualize (Figs. 10.1 and 10.2). The intraocular pressure (IOP) may be low, normal, or high [1, 6]. Retinal detachment and *phthisis bulbi* are the most feared complications of severe cases. The main source of infection is the ocular surface and adnexa [7–9]. Risk factors include blepharitis, conjunctivitis, canaliculitis, dacryocystitis, lacrimal duct obstruction, keratoconjunctivitis sicca, contact lens use, diabetes mellitus, and immunosuppression [1, 10]. Intraoperative (intra-op) risk factors include

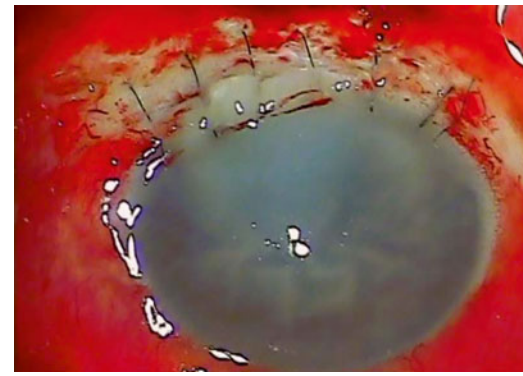

Fig. 10.1 Acute post-op endophthalmitis 1 week after uncomplicated extracapsular cataract surgery with severe corneal edema and melting at the limbus (Source: Rezende and Kickinger. Infectious Endophthalmitis. Essentials of Opthalmology, Vitreo-retinal surgery progress 3)

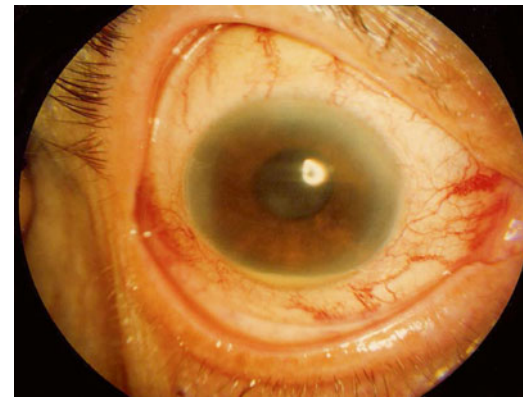

Fig. 10.2 Acute post-op endophthalmitis 36 h after uncomplicated temporal clear corneal phacoemulsification without corneal involvement (Source: Rezende and Kickinger. Infectious Endophthalmitis. Essentials of Opthalmology, Vitreo-retinal surgery progress 3)

posterior capsular rupture, vitreous loss, dropped nuclear fragments, iris incarceration in the wound, prolonged surgery (more than 60 min) [1, 10], and going through the same old wound [6]. Other suggested factors include temporal clear corneal wound compared to limbal or scleral wounds [11, 12], silicone IOL, and the method of IOL implantation [8, 10, 12, 13]. On the other hand, in a retrospective review of 3,500 cases done through a clear corneal incision between 1994 and 2004, none of the patients developed post-op endophthalmitis [14]. Postoperative risk factors include wound leak/dehiscence, poorly buried sutures, suture removal, vitreous incarceration in the surgical wound, and the presence of a filtering bleb [1].

The only strongly supported method of preoperative (pre-op) prophylaxis, besides field sterilization, is pre-op povidone-iodine 5–10 % drops [15, 16]. Other techniques such as antibiotics intra-op, subconjunctival, in irrigation solutions, and intracameral are still controversial and lack randomized research support, but there is no evidence of these precautions causing any harm [8].

The most commonly implicated organisms in acute post-op cases are coagulase-negative gram-positive *Staphylococcus*, mostly *Staphylococcus epidermidis* (*S. epidermidis*). Other organisms include other gram-positive bacteria such as *Staphylococcus aureus* (*S. aureus*), *Streptococcal* sp., *Enterococcus*, and *Propionibacterium acnes* (*P. acnes*). Gram-negative organisms include *Pseudomonas aeruginosa* (*P. aeruginosa*), *Proteus*, *Haemophilus*, *Enterobacter*, and others, but these are much less commonly involved [17, 18]. The VA outcome depends largely, among other factors, on the causative agent, with better outcomes reported in culture-negative cases or cases growing coagulase-negative gram-positive species without corneal infiltrates [18]. Factors associated with poor VA outcome include VA at presentation, corneal infiltrates/melting, other gram-positive or gram-negative species, dense vitreous debris or membranes, lid swelling, and retinal and/or choroidal detachment [18, 19].

Despite the advances in cataract surgery and the various precautions to prevent post-op infections, the rate of endophthalmitis has significantly risen during this decade compared to the previous one [11, 20, 21] with a reported incidence ranging between 0.076 % and 0.3 % [20, 22, 23].

10.2.1.1 Endophthalmitis Vitrectomy Study (EVS) Results [2, 18]

Main EVS Recommendations

- This study included 420 patients diagnosed with acute endophthalmitis after cataract surgery with IOL implantation or secondary IOL implantation.
- All patients presenting with acute post-op endophthalmitis should receive intravitreal vancomycin 1 mg/0.1 ml and amikacin 0.4 kg/0.1 ml regardless of their presenting VA.
- The use of systemic antibiotics had no beneficial effect on the final VA. Medications evaluated were intravenous ceftazidime and amikacin, with oral ciprofloxacin replacing ceftazidime in case of penicillin allergies.

Cultures

- Anterior chamber (AC): aqueous humor samples were positive in 26.9 % of cases. In 4.2 % of cases, aqueous was positive and undiluted vitreous sample was negative.
- Vitreous: non-diluted samples had 58.9 % positive cultures. Another 8.9 % had positive cultures from the vitrectomy cassette fluid alone.
- Vitreous tap/biopsy: yielded 67.4 % of positive cultures.
- Vitrectomy: yielded 73.5 % of positive cultures. There was no statistical significance between vitrectomy and vitreous tap/biopsy culture yield.
- Microorganisms: among the 291 eyes with positive cultures, 68 % showed coagulase-negative gram-positive organisms (*S. epidermidis*); 22 % showed other gram-positive organisms, like *S. aureus* and *Streptococcus*; and only 6 % showed gram-negative organisms.

Visual Acuity

- Outcomes at 9–12 months: 53 % achieved 20/40 or better, 74 % achieved 20/100 or better, and 15 % had severe vision loss of worse than 5/200.
- Only 5 % of patients had final VA of no light perception (NLP).
- Based on presenting VA, patients with light perception (LP) or NLP had a threefold higher chance to achieve 20/40 or better (33 vs. 11 %) and a 50 % lower chance to suffer from severe visual loss if treated with immediate vitrectomy and intravitreal antibiotics versus vitreous tap and inject.
- There was no statistical significance between the two treatment groups in patients presenting with VA of hand motions (HM) or better when treated with either protocol.
- Better VA outcomes were achieved in cases that had no growth or grew coagulase-negative *Staphylococcus* sp. compared to other organisms.
- Risk factors for reduced final VA included symptoms within 2 days of surgery, LP on presentation, relative afferent pupillary defect, non-intact posterior capsule, IOP less than five or more than 25 mmHg, *rubeosis iridis*, corneal infiltrate, melting and/or ring ulcer, and an absent red reflex.

Comments

- At the final visit, the media was clearer in the vitrectomy group versus the tap group regardless of presenting VA (90 vs. 83 %).
- Most common causes of poor final VA were macular complications including epiretinal membrane, edema, pigmentary changes, and ischemia.
- One-third of patients had to undergo a second procedure (vitrectomy or tap) within 36–60 h in eyes that did poorly.
- The value of intravitreal corticosteroids was not assessed.
- All patients received prednisone 30 mg PO bid for 5–10 days and received subconjunctival injection of dexamethasone 6 mg/0.25 ml.
- All patients received subconjunctival vancomycin, 25 mg/0.5 ml, and ceftazidime, 100 mg/0.5 ml.
- Due to lower intraocular side effects and superior pharmacological profile, intravitreal ceftazidime 2.25 mg/0.1 ml has replaced amikacin [24–27].

Summary for the Surgeon

- Patients presenting with LP VA should undergo immediate *pars plana* vitrectomy and intravitreal antibiotics (vancomycin and ceftazidime).
- If patients present with VA of hand motions or better post-op phaco and secondary IOL implantation, there is no difference between vitreous tap and vitrectomy with injection of antibiotics.
- Remaining media opacities were significantly less in the vitrectomy group, but this was not found to be a reason for a low final VA.
- Intravenous ceftazidime and amikacin are not recommended as adjunctive systemic therapy as they did not show any benefit.
- There is a higher chance of having a positive culture with a vitreous than with an anterior chamber sample, but overall positive results were 67.3–73.5 %.
- More favorable outcomes are associated with culture-negative or cases caused by coagulase-negative *S. epidermidis*, which are the most commonly encountered microorganism.

10.2.2 Chronic Postoperative Endophthalmitis

Chronic post-op endophthalmitis is diagnosed in cases that present beyond 6 weeks of the inciting event. The clinical picture is usually more subtle and is often misdiagnosed and treated as a sterile anterior uveitis. The signs are usually more subtle, including anterior chamber reaction responsive to corticosteroids but recurrent after cessation of treatment, granulomatous keratic precipitates, IOL precipitates, endocapsular hypopyon (Fig. 10.3), vitritis, or simply as an isolated disk edema [1, 22, 28]. The most common microorganisms involved are coagulase-negative *S. epidermidis*, *Propionibacterium acnes* (*P. acnes*), fungi (e.g.,

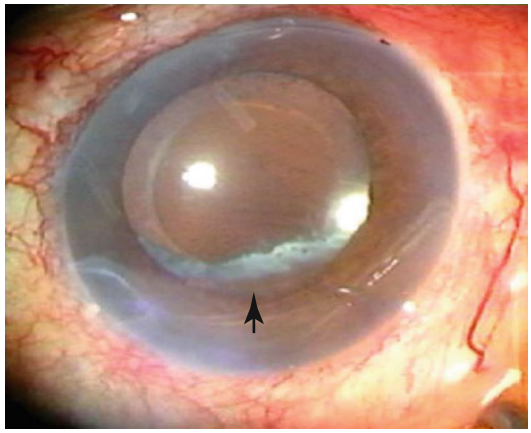

Fig. 10.3 Chronic post-op endophthalmitis with endocapsular hypopyon (*arrow*) (Source: Rezende and Kickinger. Infectious Endophthalmitis. Essentials of Opthalmology, Vitreo-retinal surgery progress 3)

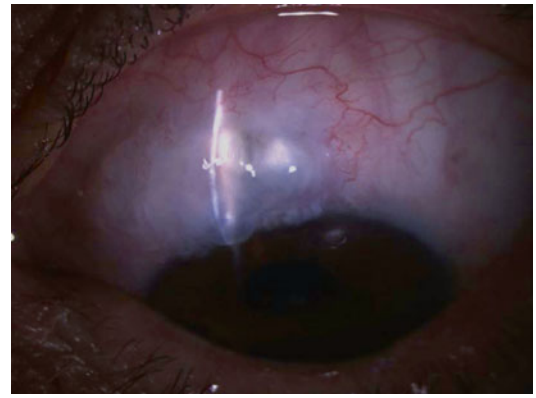

Fig. 10.4 Normal filtering bleb. Note the good height of the functional bleb and the normal vascularity surrounding the central avascular bleb (Courtesy of Dr. Mark Lesk, Maisonneuve-Rosement Hospital, University of Montreal, Montreal, Canada)

Candida parapsilosis), anaerobic *Streptococcus* species, *Nocardia asteroides*, *Actinomyces* sp., and *Corynebacterium* sp. [22]. Visual outcomes are generally better than acute cases because these are lower-virulence microorganisms [1, 3, 22, 29]. In *P. acnes* chronic endophthalmitis, the endocapsular hypopyon represents colonies of the microorganism and inflammatory cells situated between the posterior surface of the IOL and the posterior capsule (Fig. 10.3). This peculiar location is thought to protect the bacteria from antibiotics and host defense mechanisms and could explain the high recurrence rate in cases where the lens and capsule are left in place [22]. In large series evaluating the best treatment option, the following are the recurrence rates of different techniques [22, 29, 30]:

- Injection of intravitreal antibiotic: 93 %
- *Pars plana* vitrectomy (PPV) with intravitreal antibiotic: 50 %
- *Pars plana* vitrectomy with partial capsulectomy, intravitreal antibiotic, and retention of IOL: 26 %
- *Pars plana* vitrectomy with total capsulectomy, IOL removal or exchange, and intravitreal antibiotic: 0 %

The antibiotic of choice is intravitreal vancomycin 1 mg/0.1 ml. The average time for growth in cultures was between 8 and 10 days [22].

10.2.3 Bleb-Associated Endophthalmitis

The result of trabeculectomy surgery for glaucoma is a filtering bleb over the trabeculectomy site providing an alternative drainage route of aqueous humor, thus reducing IOP. This bleb should be water tight to function properly and prevent bacterial access to the intraocular environment (Fig. 10.4). The conjunctiva carries normal flora capable of causing post-op endophthalmitis including *S. epidermidis*, *S. aureus*, group C *Streptococcus*, *Bacillus* sp., *Haemophilus influenzae* (*H. influenzae*), and *P. aeruginosa* [31]. It has been documented that leaky filtering blebs allow access of the tear film into the AC [32] along with the ocular surface bacteria.

Blebitis is diagnosed when the filtering bleb becomes infected without an associated vitritis; the risk of progressing into an endophthalmitis is high if not treated urgently and properly. Bleb-associated endophthalmitis (BAE) is diagnosed when blebitis is associated with vitritis and intraocular inflammation [1]. In such cases, the most common symptoms are pain and redness. Other symptoms include blurred vision, tearing, purulent discharge, lid edema, and photophobia [1, 33] (Fig. 10.5). Risk factors include the use of 5-fluorouracil or mitomycin-C, bleb leaks,

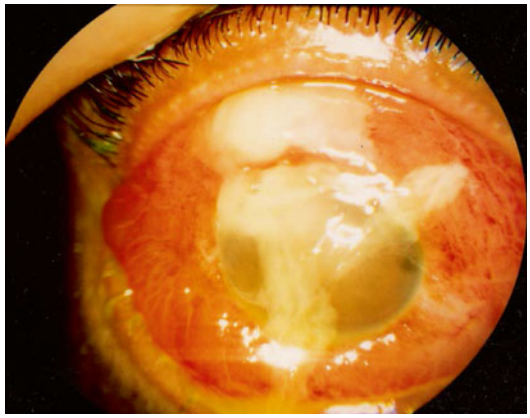

Fig. 10.5 Bleb-associated endophthalmitis 3 years after trabeculectomy with mitomycin. Culture was positive for *Streptococcus* sp. (Source: Rezende and Kickinger. Infectious Endophthalmitis. Essentials of Opthalmology, Vitreo-retinal surgery progress 3)

conjunctivitis, bleb manipulation, inferior location of bleb, trauma, and contact lens use [33–37]. The incidence of BAE ranges from 0.2 % to 9.4 % which is higher than other intraocular surgeries and is believed to be largely due to the use of antifibrotic agents [33–35]. Bleb-associated endophthalmitis is divided into early, if presented within 6 weeks post-op, or late (may happen even many years after surgery). In the early period, the most common microorganisms are *S. epidermidis* and *S. aureus*, while in late cases *Streptococcus* sp. *and H. influenzae* are more frequently cultured [34, 36, 37]. Cultures were found to be positive in 67–97 % of cases [34]. Visual acuity outcome is generally poor with final VA better than 20/400 ranging between 31 % and 65 %. Outcomes post-*Staphylococcal* endophthalmitis seem to be more favorable than post-Streptococcal endophthalmitis [34, 36]. The EVS did not include patients undergoing filtering glaucoma surgery, and extrapolation of its data should be done carefully. Although no randomized controlled clinical trial has been conducted to date, the surgical outcomes for BAE seem to be better with prompt *pars plana* vitrectomy and intravitreal antibiotics than with vitreous tap and intravitreal antibiotics regardless of time of onset and pre-op VA [36]. Besides intravitreal antibiotics, topical fortified drops (vancomycin 50 mg/ml and gentamicin 15 mg/ml) and oral fourth-generation fluoroquinolones are used to treat the infected bleb [35, 37, 38]. If a leaky bleb is present in association with blebitis and endophthalmitis, it is recommended to perform a bleb excision and conjunctival advancement in addition to *pars plana* vitrectomy with topical and intravitreal antibiotics [36, 39].

10.2.4 Post-intravitreal Injection Endophthalmitis

The number of intravitreal injections performed has increased significantly over the last decade, and, accordingly, the rate of post-intravitreal injection endophthalmitis (IVIE) has also increased. In a recent review by Moshfeghi et al., the rate of IVIE was 0.02–0.14 % [40]. The most common organisms are *S. epidermidis*, *S. aureus*, *Streptococcus* sp., and, usually in case of drug contamination, fungal species. The rate of postinjection *Streptococcal* endophthalmitis is three times higher than that in post-op cases [41]. This could be explained by the fact that surgical masks were not routinely worn during the office-based procedure. In an experiment simulating the setting of intravitreal injections, oral flora was found to grow on culture plates significantly higher when the surgeon and the patient were not wearing surgical masks than in cases when they wore them, avoided talking, or turned their faces away while talking; the rate of *Streptococcal* sp.-positive cultures was found to be 67–83 % [42, 43]. In another study, they compared bacterial growth on culture plates while wearing surgical masks, in silence, and with pretreatment of the plates with 5 % povidone-iodine without surgical masks or silence. The least growth was found on the povidone-iodine pretreated plates [43]. In comparing office-based setting versus operating room-based setting, there does not seem to be a significant difference in the rate of endophthalmitis or the causative microorganisms when surgical masks are used during office-based intravitreal injections [44]. Another important cause of IVIE is the contamination of the medications prepared at compounding pharmacies. Several outbreaks have been reported with mainly *Streptococcal* or fungal species resulting

in very poor outcomes [45–47]. If contamination is suspected, testing of unused syringes containing the medication from the same lot is warranted, and it should be reported to the local authorities.

We conducted a retrospective chart review of acute endophthalmitis (AE) post-intravitreal bevacizumab injection in cases done by one surgeon. The surgeon, nurses, and patients wore surgical masks during the procedures done in the minor procedure room at the Department of Ophthalmology ambulatory clinic, Maisonneuve-Rosemont Hospital, University of Montreal, Quebec, Canada. The rate of IVIE was found to be 0.13 % (4 of 3,088 injections); two were culture-positive for coagulase-negative *S. epidermidis*, and two had no growth (Table 10.1). All patients underwent tap and injection of vancomycin 1 mg/0.1 ml and ceftazidime 2.25 mg/0.1 ml upon diagnosis of IVIE. Three of them underwent a later 25-gauge (25g) MIVS to clear vitreous opacities. The fourth patient developed a central retinal artery occlusion during the period of recovery from IVIE and refused to undergo further procedures. All four patients improved after tap and injection of antibiotics, two out of four (culture-negative) patients improved better than their VA before endophthalmitis had developed, and three out of four continued to receive intravitreal bevacizumab (IVB) without any further infectious complications [48].

The outcomes of IVIE also depend on the causative organism, where coagulase-negative *S. epidermidis* cases or culture-negative cases have a better final VA outcome than post-Streptococcal cases. The final VA post-IVIE when surgical mask is used was found to be as favorable as post-phaco and IOL implantation acute endophthalmitis with a good percentage of patients returning to baseline VA [49]. Treatment may be guided by the EVS study, but surgeons should carefully extrapolate these results and decide on each patient's treatment individually. In this particular entity, we prefer to start the treatment with tap/inject to try to preserve the vitreous as the pharmacokinetics of intravitreal injections may be significantly altered in vitrectomized eyes (Fig. 10.6) [50].

Table 10.1 Visual acuities and culture results of the four patients that had post-IVB endophthalmitis

Patient	VA pre-IVB	VA at AE	Final VA	Organism	IVB post-AE
1	20/80	20/50	20/60	No growth	Yes
2	20/50	HM	20/40	No growth	Yes
3	20/60	LP	CF	*S. epidermidis*	No
4	20/50	CF	20/150	*S. epidermidis*	Yes

Source: Haji et al. [129]

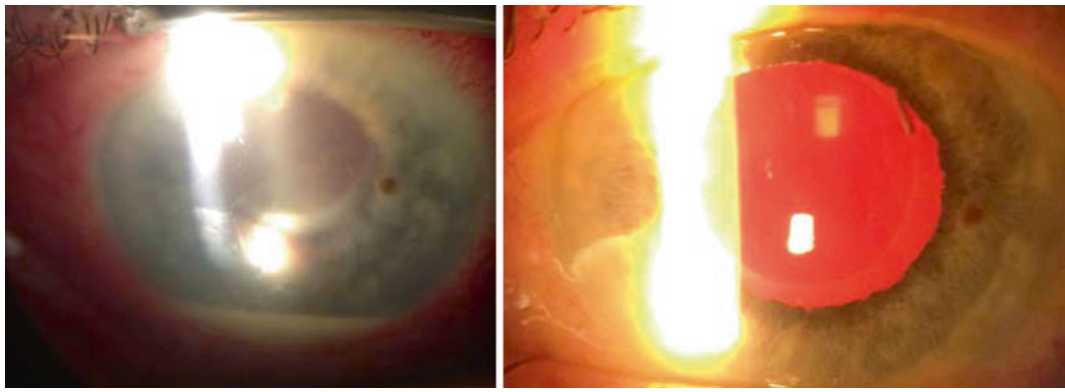

Fig. 10.6 On the *left*, 4 days post-ranibizumab intravitreal injection-related infectious endophthalmitis. On the *right*, good response after 2 weeks post-tap/inject with vancomycin 1 mg/0.1 ml and ceftazidime 2.25 mg/0.1 ml. Culture grew *Staphylococcus epidermidis*. Patient continued to receive regular anti-VEGF injections without any subsequent infection

10.2.5 Post-vitrectomy Endophthalmitis

This clinical entity is rare and carries poor prognosis for the affected eye. More detailed discussion will follow in the MIVS section.

10.2.6 Post-Type-1 Boston Keratoprosthesis Endophthalmitis

Type-1 Boston permanent keratoprosthesis is a polymethylmethacrylate device in a collar button shape that is used to restore the clarity of the visual axis in cicatricial corneal diseases that are not amenable to conventional corneal transplant [51] (Fig. 10.7). This procedure allows a connection between the sterile anterior chamber environment and the ocular surface with its flora and external pathogens [52]. In a review of literature from 2001 to 2011 by Robert et al., the prevalence of post-permanent KPro endophthalmitis (KPE) was found to range from 0.0 % to 12.5 %. Risk factors include Steven-Johnson syndrome, ocular cicatricial pemphigoid, noncompliance with antibiotics, nonuse of vancomycin, poor contact lens hygiene, corneal melting, and infectious keratitis. The most common causative agents are gram-positive bacteria (60 %) [52] with one study reporting that 10 out of 15 gram-positive cultures grew *Streptococcus viridans* [53]. Other organisms include *Staphylococcal* sp., gram-negative bacteria, and fungi (Fig. 10.8). The most important prevention method is using vancomycin drops in addition to the traditional quinolones; this has significantly reduced the prevalence of KPE [52, 53]. This entity tends to present in the late postop period, and the outcomes depend on the causative microorganism but are usually poor due to the higher prevalence of *Streptococcus* sp. A high index of suspicion is important in cases of retroprosthesis membrane and vitritis with or without pain, and B-scan ultrasound is an important diagnostic tool in cases of poor visualization [54, 55].

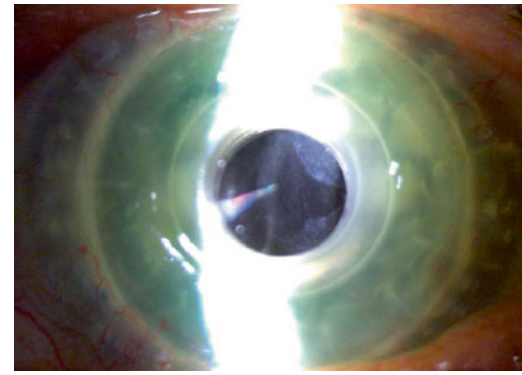

Fig. 10.7 Type-1 Boston keratoprosthesis

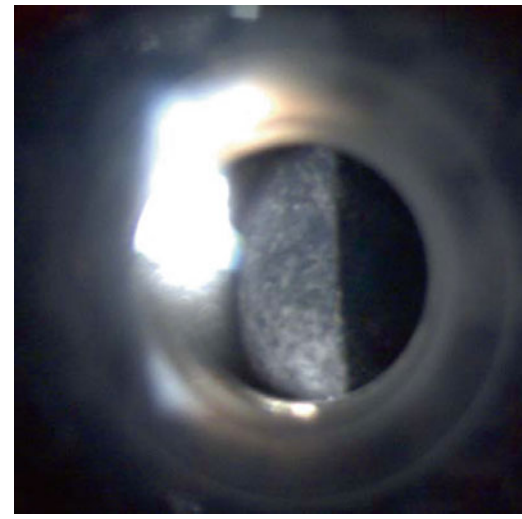

Fig. 10.8 Candida albicans endophthalmitis post-type-1 Boston keratoprosthesis. Note inflammatory debris accumulated at the posterior surface of the prosthesis

10.2.6.1 Summary for the Surgeon

- In chronic endophthalmitis, PPV with total capsulectomy and intraocular lens removal plus intravitreal vancomycin injection is the procedure associated with the lowest recurrence rate.
- Bleb-associated endophthalmitis is characterized by pain and decreased vision with mucopurulent infiltrate within the bleb, hypopyon, and vitritis.
- Risk factors for BAE include the use of antifibrotic agents, blebitis, inferiorly located blebs, conjunctivitis, bleb manipulation, leaky blebs, and contact lens use.

- In post-intravitreal injection endophthalmitis, there is a threefold higher risk of *Streptococcus* sp. when compared to post-op endophthalmitis, and this is most likely due to contamination by oral flora if surgical mask is not used. Precautions, such as avoiding speaking or using surgical masks, should be taken to minimize injection-field contamination. Compounding pharmacy contamination is another cause of virulent microorganisms with poor-outcome IVIE.
- Most patients should be encouraged to resume intravitreal injections, if still indicated, after the resolution of endophthalmitis.
- No significant differences were found between the rate and causative microorganism of IVIE when office-based setting versus operating room-based setting was compared when surgical masks were used.
- Endophthalmitis post-KPro is mostly due to gram-positive bacteria, mainly *Streptococcus* sp. and *Staphylococcal* sp., with generally poor outcomes.
- Post-KPro surgery prophylaxis with vancomycin drops in addition to quinolones has significantly reduced the prevalence of PKE.
- As the EVS included only acute post-op cases after cataract surgery or secondary IOL, extrapolation of its data should be done carefully for other entities. The surgical outcome for BAE seems to be better with prompt pars plana vitrectomy and intravitreal antibiotics, while there is no consensus on the best treatment for IVIE or PKE.

10.2.7 Ultrasound in Endophthalmitis

The diagnosis of endophthalmitis is mainly done on clinical examination, but valuable information can be obtained from A- and B-scan ultrasonography of the affected eye at presentation. Echographic findings include vitreous opacities; vitreous membranes (Fig. 10.9); vitreous incarceration; location of persistent vitreous attachments; vitreoretinal traction; retinal detachment

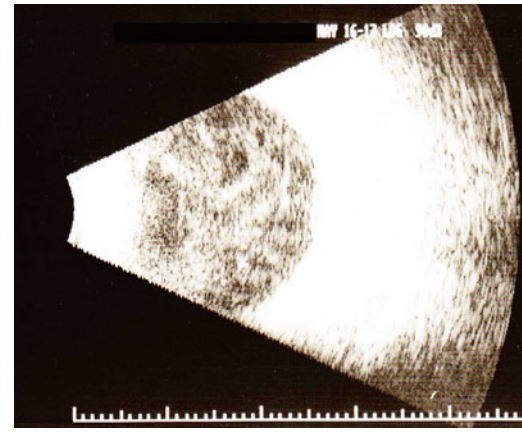

Fig. 10.9 Severe vitreous opacities and membranes in a case of acute endophthalmitis post-intravitreal injection of bevacizumab

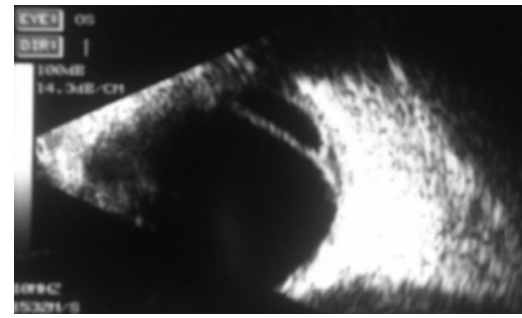

Fig. 10.10 Tractional retinal detachment in a case of endophthalmitis post-type-1 Boston keratoprosthesis

(RD) (Fig. 10.10) and its extent; subretinal opacities; presence of choroidal detachment (CD) and its size, location, and type (serous vs. hemorrhagic); retinochoroidal thickening; choroidal calcification; optic nerve swelling; scleral thickening; lens status; IOL location; retained nuclear fragments; globe size; and orbital inflammation [19, 56, 57]. The gain should be increased between 84 and 90 dB, as inflammatory cells and membranes have low reflectivity [58]. Several study groups found significant negative correlation between these signs and the final VA [19, 57, 59].

A study by Dacey et al. reviewed records of 137 endophthalmitis patients. They found that 69 % (24/35) of eyes with vitreous opacities of severe density had a final VA worse than 1/200

versus 33 % (10/30) of eyes with mild opacities. Also, 91 % (30/33) of eyes with final VA of NLP had moderate to severe opacities density on the initial echography. When they compared the final VA of eyes that had vitreous membranes on the initial echography (20/137) to those that had none, 55 % (11/20) versus 25 % (29/116) had final VA of NLP, respectively. In eyes that had RD on initial echography (25/137), none had final VA better than 20/200. Fifty-six percent of eyes with RD had final VA of NLP versus 21 % of eyes without RD. Of note, the status of the macula (macula-on vs. macula-off) had no statistical significance on final VA. The coexistence of choroidal detachment on presentation had a significant impact on final VA. Eighty-one percent (22/27) of eyes with CD on the initial ultrasound had final VA worse than 1/200 versus 47 % (50/106) of eyes that had no CD. Choroidal detachment was the strongest indicator of final VA worse than 20/100. They also found a correlation between B-scan findings and the infecting microorganism. *Streptococcal* endophthalmitis cases were at least twice more likely to develop severe vitreous opacities or vitreous membranes on the initial presentation than other infecting microorganisms (56 % and 45 %, respectively). Gram-negative endophthalmitis was significantly correlated with the presence of choroidal detachment but with less significant vitreous opacities [19]. Another valuable use of pre-op ultrasound is to confirm the location of retinal and/or choroidal detachment in relation to the area of intended sclerotomy placement, for either a vitreous sample or surgery, thus avoiding more potential serious complications [58].

10.3 Current Surgical Techniques

10.3.1 Office-Based Vitreous Tap/Biopsy

- Explain to the patient the steps of the procedure, risks, and benefits and obtain a consent form.
- Apply topical proparacaine 0.5 % drops followed by povidone-iodine 5 % solution.
- The authors prefer using retrobulbar/peribulbar anesthesia (as described below). As the eye is usually markedly inflamed, this type of anesthesia helps the patient to be more comfortable during the procedure and will relieve his/her pain for approximately 2 h.
- Under sterile technique, withdraw 0.1 ml of vancomycin (1 mg) and 0.1 ml of ceftazidime (2.25 mg) and place them on a sterile drape.
- Place a sterile lid speculum and apply another drop of 5 % povidone-iodine at the site of entry.
- A transconjunctival vitreous tap is done using a 25-g or 26-g needle on a 1-ml syringe. We recommend entering in an oblique fashion to avoid wound leakage; stabilizing the eye with a sterile cotton-tipped applicator will facilitate this maneuver.
- In case of pseudophakia, aspirate in the anterior vitreous right behind the lens where the anterior liquefied vitreous is usually located. This will minimize the chance of causing vitreous traction and vitreous strand incarceration at the entry wound. In case of phakic patients, this is not recommended due to the risk of traumatic cataract formation.
- Withdraw 0.2–0.5 ml of liquefied vitreous while gauging the IOP with the cotton-tipped applicator then remove the needle and roll the conjunctiva over the wound site.
- The vitreous sample should be capped, labeled with the patient's information, and placed on the sterile drape.
- Using a 30-g needle, the antibiotics should be injected consecutively at the same distance from the limbus. The first entry site should be avoided, and if the eye is too soft, we recommend counter traction with toothed forceps.
- The obtained sample should be inoculated directly onto culture media including blood, chocolate, and Sabouraud agars and meat broth media. An inoculum should also be placed onto a glass slide for gram staining and microscopy.
- In case of an available microbiology lab, the sample should be taken there directly and labeled as urgent. Communication with the

Fig. 10.11 One-port 23-g Intrector® system (Insight Instruments, Stuart, FL) using the indirect ophthalmoscopy for vitreous biopsy

microbiology team could not be overemphasized.

- Alternatively, portable vitrectomy systems used in an ambulatory setting may be used for safer vitreous biopsy, minimizing vitreous traction. Currently there are two systems available. One is a 25-g sutureless Retrector® system (Insight Instruments, Stuart, FL). This is a portable, battery-powered system with a maximum cut rate of 600–1,250 cpm that features a single-use retractable sheathed guillotine 25-g cutter with a built-in 23-g needle. The needle is introduced bevel down through displaced conjunctiva in an oblique one-plane tunnel into the vitreous cavity 3–4 mm from the limbus. This one-port technique can be done using the light source from the surgical microscope or using the indirect ophthalmoscope for visualization (Figs. 10.11 and 10.12). A newer system using a larger vitrectomy unit is also now available for office-based vitreous biopsy (VersaVIT®, Synergetics Inc, O'Fallon, MO). An additional interesting feature of this equipment includes the usage of 27-g valved cannulas. This allows surgeons, through the same one-port sclerotomy, to perform the vitreous biopsy and inject antibiotics. In an office-based environment, the presence of valves and the smaller diameter of the cannulas may increase safety and decrease contamination from external sources.
- The undiluted sample is cut and aspirated using a sterile 1.0-ml syringe connected to the aspiration line of the portable vitrector. A minimum of 0.3–0.5 ml of undiluted vitreous fluid is cut and removed from the mid-vitreous through controlled manual aspiration. No infusion line is necessary for this biopsy procedure.

10.3.2 Anesthesia

Although some surgeons advocate general anesthesia for longer *pars plana* vitrectomy cases because of the difficulty in achieving adequate anesthesia in an inflamed, painful eye, we advocate performing this surgery under retro-/peribulbar anesthesia. Injection of 5 ml of 2 % lidocaine without epinephrine mixed with 5 ml of bupivacaine 0.5 % in a 10-ml syringe and 1.5-in 25-g hypodermic needle is used in combination with light sedation of the patients. This usually achieves the desired anesthesia keeping them comfortable throughout the procedure. Care

Fig. 10.12 Portable vitrectomy machine with small-gauge valved cannulas/trocars (*bottom left*) and small-gauge vitrectomy kit (VersaVIT®, Synergetics Inc, O'Fallon, MO)

should be taken not to have subconjunctival anesthetic infiltration, as this could render placement of the cannulas more difficult and increases the risk of cannula extrusion during surgery.

10.3.2.1 Key Concepts for MIVS in Endophthalmitis

- Always begin by securing the original surgical wound with sutures even if it appears stable (Fig. 10.13).
- In case of reduced visibility of the posterior segment, it is safer to place the infusion line in the AC until the visual axis is cleared.
- In case of post-trabeculectomy endophthalmitis with conjunctival dehiscence, start with delicate closure of the conjunctiva paying extra attention not to manipulate the tissues excessively to avoid tearing the friable conjunctiva. In case of pus collection within the bleb, it should be excised, and if necessary, the sclera sutured close with a scleral patch graft.
- Eyes with endophthalmitis can be hypo- or hypertensive. Wound structuring and transconjunctival suturing are more challenging in cases of low IOP and inflamed conjunctiva.

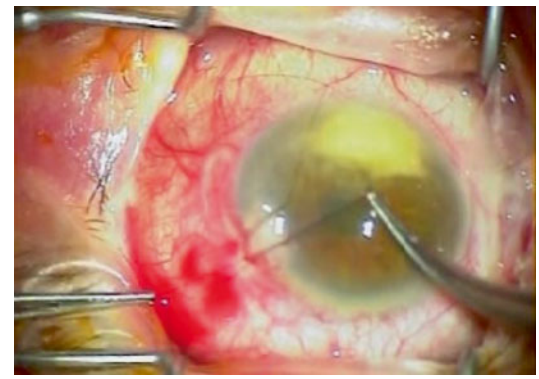

Fig. 10.13 Clear corneal wound closure with 10-0 nylon (Source: Rezende and Kickinger. Infectious Endophthalmitis. Essentials of Opthalmology, Vitreoretinal surgery progress 3)

- Caution should be exercised to avoid excessive infiltration of the conjunctiva and Tenon's capsule during retrobulbar anesthesia as this will render surgical wound construction and placement of the cannulas at the proper distance from the limbus quite difficult. In addition, this increases the risk of extrusion of cannulas during the procedure.

- Avoid using the original wound for working in the anterior segment as this increases risk of endophthalmitis [6].
- Retinal detachment in an infected eye is a very serious complication with limited visual recovery.

10.3.3 MIVS for Infectious Endophthalmitis

Over the last decade, the technology used in vitrectomy surgery has evolved, and the safety of MIVS has strong support in the literature [60, 61]. This section will address MIVS for infectious endophthalmitis after various surgical procedures, its outcomes, as well as endoscopy-guided MIVS. The authors use the Constellation ULTRAVIT 25+ system (Alcon Labs, Fort Worth, TX, USA).

10.3.3.1 Surgical Preparation

Preoperative disinfection of the eye and periocular skin is done using 5 % povidone-iodine [15, 16] left on the skin for 30 s. A drop of 5 % iodine is also installed onto the eye prior to starting the case; both measures seem to reduce the incidence of postoperative endophthalmitis [15, 16].

10.3.3.2 Acute Infectious Endophthalmitis

For eyes that had undergone phaco and IOL implantation or secondary IOL implantation, the first step is to secure the surgical wound by placing 10-0 nylon sutures (Fig. 10.13) for either corneal or limbal incisions.

- Start by collecting a non-dilute vitreous sample.
- Keep the infusion line primed and within the operating field to avoid complications secondary to ocular hypotension while obtaining the non-dilute sample.
- Using the 25-g valved cannula system, first create a scleral tunnel in the inferotemporal quadrant at 3.0–3.5 mm from the limbus and place the infusion line closed.
- Place the second sclerotomy in the superotemporal quadrant and insert the vitrector with a 3-ml syringe connected to its aspiration line and start collecting the specimen at a cut rate of 5,000 cpm and aspiration of 650 mmHg from the mid-vitreous cavity. The assistant starts withdrawing the non-diluted sample judiciously to obtain 0.2–0.5 ml. Monitor IOP using a cotton-tipped applicator.
- Next step is to clean the anterior chamber.
- Clamp the infusion line to disconnect it and place a plug on its cannula (in case there is no valved system).
- With the infusion line placed anteriorly and set at 35 mmHg, create a second corneolimbal paracentesis to introduce your instruments.
- Start by clearing the hypopyon/debris using the vitrector at a maximum cut rate and aspiration. At this point, the infusion may be raised to 60 mmHg.
- In case of posterior synechiae, place a bent 26-g needle on a viscoelastic syringe to dissect away the iris from the IOL/anterior capsule/fibrin. Use the needle tip to cut the synechiae while injecting the viscoelastic to lift up the iris.
- Usually, a cyclitic membrane forms across the pupil and over the crystalline lens/IOL/iris affecting visualization of the posterior segment. This layer is sometimes hard to recognize, but if the IOL seems blurry, there is a good chance that it is covered with fibrin.
- Using a 25-g end-grasping membrane forceps, the authors prefer using Alcon 25-g MAXGRIP forceps (Alcon Labs, Fort Worth, TX, USA), peel that layer off the IOL and iris. A bimanual approach is sometimes necessary to dissect these membranes using the forceps and the vitrector.
- When working with the vitrector over the iris, it is safer to turn the port 90–180° away to avoid inadvertent trauma.
- In case of significant AC bleeding, viscoelastic can be used as a tamponade to control bleeding and be able to complete the posterior segment surgery. Always keep in mind to remove the viscoelastic from the AC at the

conclusion of surgery to decrease immediate post-op pressure spikes.

- When the AC work is done, return the infusion to the inferotemporal *pars plana* cannula and close all paracentheses with 10-0 nylon sutures. Before opening the infusion, confirm that it is still placed within the vitreous cavity. If visualization is still poor, the light pipe can be passed through the cannula to confirm its position.
- Place the third 25-g valved cannula on the superonasal quadrant at 3.0–3.5 mm from the limbus for the light pipe. In case of poor visualization due to severe corneal edema, and in the lack of an endoscopy unit, only two ports are sufficient to carry out a "blind" core vitrectomy.
- Newer and stronger light sources are preferred due to media opacities. A noncontact wide-angle viewing system is recommended to avoid corneal abrasion in an infected eye (some surgeons remove the corneal epithelium to improve visualization and penetration of topical medications, but we strongly discourage it).
- Carry on core vitrectomy to remove as much inflammatory debris as possible, but the extent of peripheral vitrectomy is governed by the clarity of the media. Attempts to detach the posterior vitreous and peripheral vitreous shaving are risky and can induce tears due to the friable and inflamed retina. These steps are rarely attempted in such conditions without endoscopy use.
- Inspect the retina looking for tears or areas of necrosis. If present, they should be treated with laser photocoagulation (to encircle the lesions).
- At the conclusion of vitrectomy, perform a partial air-fluid exchange (one-third air) for internal wound tamponade.
- To avoid the syringe-plunger effect while removing the cannulas, use the angulated McPherson forceps to slide the cannula over the light pipe, withdraw the light pipe in the same orientation of the scleral tunnel, and roll the conjunctiva over the wound using a cotton-tipped applicator. This reduces vitreous prolapse from the wound, thus reducing the risk of post-op hypotony and reinfection [62, 63].
- The antibiotics (vancomycin 1 mg/0.1 ml and ceftazidime 2.25 mg/0.1 ml) can be injected through a valved cannula.
- Remove the infusion line along with the cannula at once, using the angulated forceps.
- Careful wound examination for leakage should be done prior to conclude the case. We recommend cauterizing each transconjunctival wound to seal them and avoid further contamination. One should have a low threshold to suture a suspicious wound using 6-0 or 7-0 Vicryl.
- Take care when removing the lid speculum. It may compress the eye and be responsible for immediate post-op hypotony.
- The non-dilute vitreous along with the vitrectomy cassette should be labeled and sent for microbiological examination. Report to microbiology any prior antibiotics usage.
- Prescribe moxifloxacin or gatifloxacin drops every 2 h, prednisolone acetate 1 % q1 h, atropine 1 % BID, and oral prednisone 4–60 mg QD along with a proton pump inhibitor to protect the patient's stomach.
- In case of contraindication to systemic prednisone, sub-Tenon injection of 1-ml triamcinolone acetate 40 mg/ml could be used, but periocular or intraocular steroids are not used routinely.
- All patients should be followed up closely to evaluate the evolution of their disease. Usually, if the microorganism is sensitive to the injected antibiotics, the patient should feel significantly less pain the next day.

Comments

In cases where severe corneal edema or even corneal melting is present, a two-port 25-g core vitrectomy or even only the office-based vitreous biopsy will suffice to obtain a sample for microbiological analysis and intravitreal antibiotics injection. Care should be taken to stay within the center of the vitreous cavity and avoid unnecessary movements to avoid inadvertent retinal

breaks. Another valuable option that we prefer is to perform endoscopic-guided MIVS that will be described in details in the next section.

Management of the anterior segment using 25-g instruments seems more precise and less traumatic than larger gauge instruments.

10.3.3.3 Endoscopy-Guided Vitrectomy for Infectious Endophthalmitis

The principles and other indications of endoscopic surgery are discussed in another dedicated chapter. We will emphasize here on the specific case of endoscopy-guided *pars plana* vitrectomy for infectious endophthalmitis.

The anterior segment management is similar to the 25-g MIVS approach. Even though endoscopy is used to bypass the standard view through the pupil and lens/IOL, it is still important to perform the anterior chamber cleaning to allow you to see the tips of the instruments in the vitreous cavity making your intraocular orientation easier.

The authors use Endo Optiks ECP 23-g or 19-/20-g system (Endo Optiks, Little Silver, NJ, USA).

The following is a summary of the surgical procedure using 23-g or 19-/20-g endoscope:

- First, obtain the non-dilute vitreous sample and place the infusion line as previously described. Using the valved 23-g trocar system (Alcon Labs, Fort Worth, TX, USA), create two-step beveled scleral tunnels in the superonasal and superotemporal quadrants. This will allow alternating the port of entry of the endoscope and instruments, thus giving an easier 360-degree access to the anterior structures. Furthermore, the infusion line (in case of 23-g infusion) can be placed in one of the superior cannulas to allow a different angle of access/view.
- In case of 19-/20-g endoscopy probe, we prefer using 25-g cannulas and instrumentation. We recommend placing the 25-g cannula in the quadrant of the surgeon's dominant hand for the vitrector/forceps, and the endoscope should be held with the nondominant hand.
- Using a bipolar flat-tip cautery, cauterize the superficial conjunctival vessels where the 19-gauge sclerotomy will be placed.
- Pre-place a double-bite 6-0 Vicryl transconjunctival scleral suture and create a straight 19-g sclerotomy using an MVR blade at 3.0–3.5 mm from the limbus between the pre-placed sutures. Care should be taken to form a wound that will barely allow the passage of the endoscope, as a large incision will allow excessive flow of fluid and may increase the risk of intra-op hypotony, conjunctival infiltration, increased bleeding, and internal dislodging of the 19-/20-g plug (Fig. 10.14).
- First thing after introducing the endoscope is to orient yourself inside the eye by advancing the endoscope until its tip can be seen behind the IOL through the operating microscope (sometimes as a fuzzy light due to corneal or IOL opacities).
- Next, introduce the vitrector while aiming the endoscopic probe toward it until it is visualized on the endoscopy unit screen. Due to dense vitreal opacities, usually the shiny reflection off the vitrectomy probe may be all that it is seen in the beginning (Fig. 10.15).
- Start with anterior vitrectomy behind the IOL in order to have a clear pocket of vitreous to better visualize the vitrector and adjust the orientation of the endoscope.
- Once orientation is established, the surgery should be carried on under endoscopic visualization.
- Start moving cautiously toward the periphery making sure to always visualize the vitrector tip. Keeping in mind the contour of the eye wall, this technique will allow you to perform reasonable peripheral shaving with low risk of retinal tears. Meticulous shaving should be avoided not to induce iatrogenic breaks.
- Continue with the core vitrectomy toward the posterior pole. Under endoscopic view, you will have to get fairly close to the internal ocular structure to see them; advance cautiously to avoid iatrogenic trauma (Fig. 10.15).
- An attempt to detach the posterior hyaloid should only be done if a good view of the retina allows you to exclude retinal necrosis, vitreoretinal traction, or tears. Otherwise, this part of surgery should be abandoned. Using

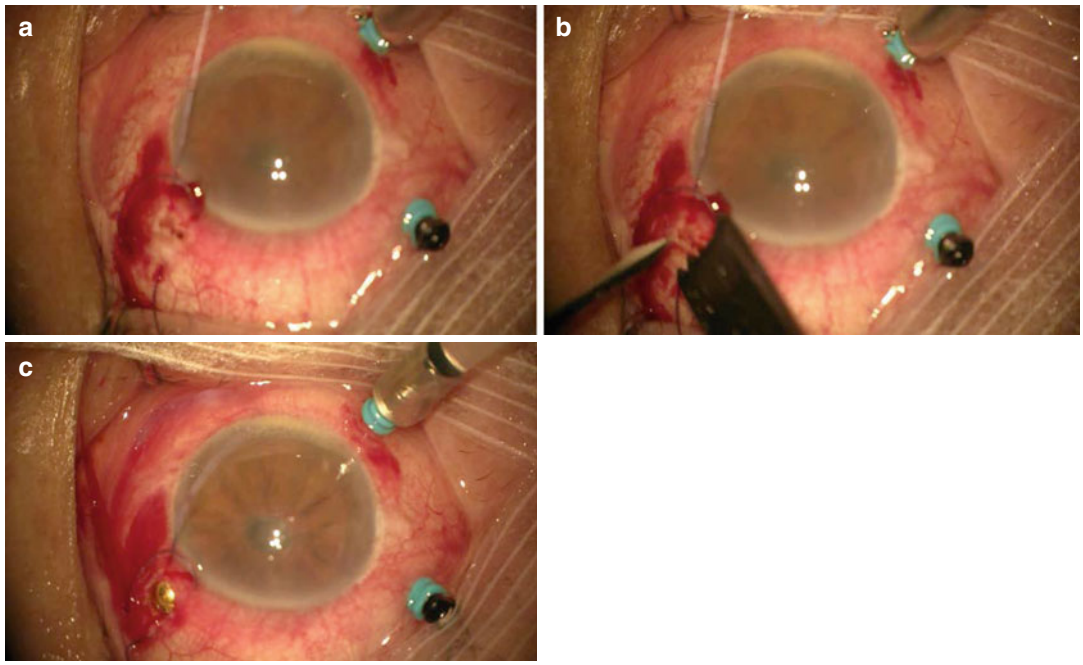

Fig. 10.14 Chronic endophthalmitis post-phaco. Preplacement of 6-0 Vicryl with cauterization of conjunctival vessels (**a**). 19-/20-g sclerotomy placed 3 mm from the limbus (**b**). The size of the sclerotomy should be wide enough to fit the endoscope but avoid leakage or slippage of the scleral plug (**c**)

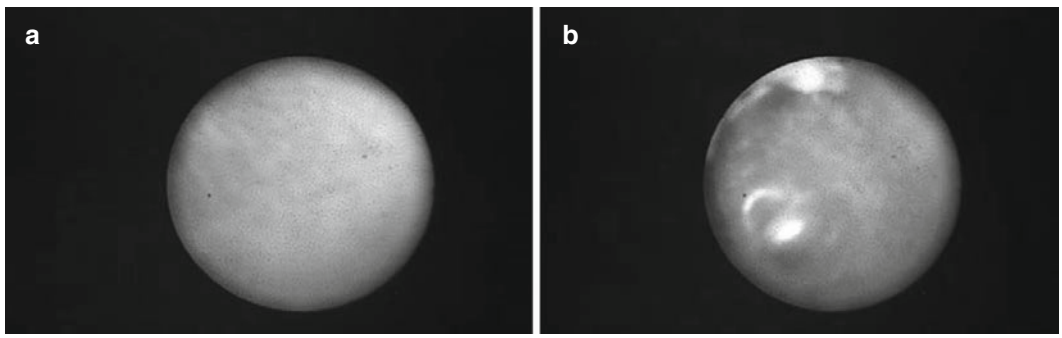

Fig. 10.15 Post-trabeculectomy with antimetabolites endophthalmitis. Severe corneal edema avoiding a posterior view through the operating microscope (**a**). Improved visualization of the optic nerve and retina under endoscopic view in this eye with severe corneal edema (**b**). Note the typical ischemic looking retina with multiple intraretinal hemorrhages commonly present in severe infectious endophthalmitis

the aspiration function at maximum of the vitrector without cutting, the posterior hyaloid detachment should start around the optic disc. Preferably, posterior hyaloid detachment should extend only as far as the equator. If the vitreous is found to be adherent, then this part of the procedure should be abandoned.

- The endoscopic technique provides invaluable information about the status of the macula and the retinal vasculature during the procedure, and it can provide prognostic indicators for the post-op course (Fig. 10.16).
- Examine the anterior retina, *pars plana*, *pars plicata*, and the lens capsule complex, taking

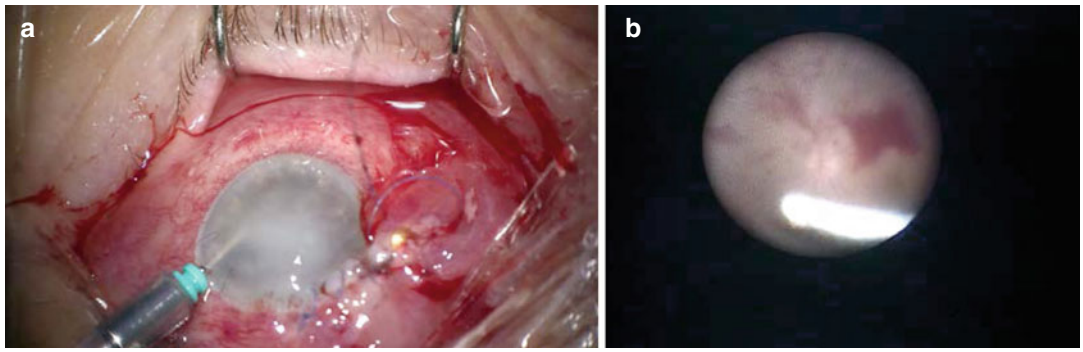

Fig. 10.16 Post-trabeculectomy with antimetabolites endophthalmitis. Limited view at the start of vitrectomy (**a**) with visualization of the vitrector tip behind the lens for orientation (**b**)

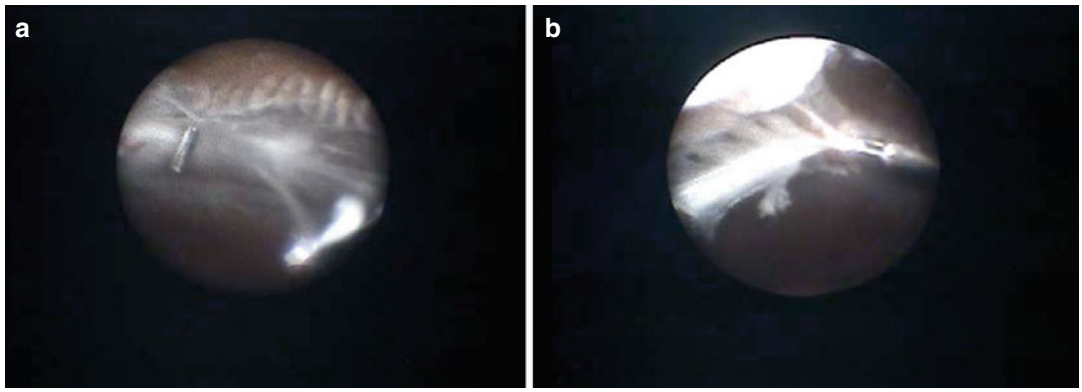

Fig. 10.17 Anterior vitreous base/ciliary body fibrotic membranes surrounding the entry port in a case of chronic endophthalmitis (**a**). Peeling under endoscopic view was done using the vitrector and 25-g end-grasping forceps (**b**)

note of any anterior cyclitic membranes in evolution, peripheral tractional or rhegmatogenous retinal detachment, and the position of the IOL in the bag or sulcus (Fig. 10.17).

- Laser photocoagulation should be applied around suspicious areas of retinal breaks or necrosis.
- At the end of the procedure, perform a one-third air-fluid exchange prior to intravitreal antibiotics/antifungal injections. In case of 19-/20-g endoscopy, withdraw the endoscope and tie the pre-placed Vicryl suture before injecting the antibiotics.
- Then withdraw the cannulas over the light pipe to avoid the syringe-plunger effect and tie the pre-placed sutures.

Comments

Up to date, there is limited research on the advantages and outcomes of endoscopy-guided vitreoretinal surgery. In one retrospective chart review, 15 patients diagnosed with acute endophthalmitis due to variable reasons (including penetrating trauma; cataract surgery; bleb-related, retinal detachment surgery; and endogenous) had undergone endoscopy-guided *pars plana* vitrectomy. The authors did not mention the gauge of the vitrector used during the study period, but 20-g vitrectomy was the standard of care in most centers at that time. Fourteen out of 15 patients had culture-positive results, and 7 of 15 patients (46.7 %) had VA better than 20/200 at 6-month follow-up. Two had surgical related complications, both being retinal detachments

diagnosed at 1-week post-op. Intraoperatively, two patients had retinal breaks and two had retinal detachments; all six patients, including the two post-op retinal detachments, were successfully treated [64].

In another review of 21 cases of acute postoperative endophthalmitis with retinal detachment, all cases were successfully repaired using endoscopy-guided 20-g vitrectomy with C3F8 (2 cases) or silicone oil tamponade (19 cases). Eleven of the 21 obtained vitreous samples were positive, and 2 cases underwent evisceration during the follow-up period due to uncontrolled recurrent infection/inflammation [65].

Endoscopy-guided MIVS is an underutilized and valuable technique that enables us to manage cases where media opacities would render the procedure extremely difficult and very limited due to the reduced intra-op visualization. The main difficulty of this surgery lies in the fact that we are used to operate through a surgical microscope with three-dimensional perception while operating using an endoscopic view on a screen gives us a two-dimensional perception only. This requires a certain period of training to be able to adjust to this new technique. Another important factor is to plan a temporal versus superior approach and the site of the pathology to be treated, as access to anterior and superior pathology is very difficult through superior cannulas using the only available straight instruments. In our experience, the outcomes of infectious endophthalmitis with endoscopy-guided MIVS seem promising. Another useful option is to use a 23-g vitrector instead of 25g. Because the endoscope is 23g, using 25-g equipment increases cost due to the need to open two different packs.

The surgical results and post-op complications are comparable between 20-, 25-, and 23-gauge vitrectomy systems. In recent systematic review of literature and several retrospective case series, the outcome and rate of complications post-23-g MIVS was comparable to other methods [66–69]. Wound structuring in a beveled two-step procedure is superior to direct entry [69, 70].

Further details on endoscopy-guided MIVS are found in a separate chapter about endoscopy.

10.3.3.4 Pars Plana Vitrectomy and Silicone Oil Tamponade

In vitro studies by Ozdamar et al. have shown that silicone oil reduced colony-forming units of *S. aureus*, *S. epidermidis*, *P. aeruginosa*, *Candida albicans* (*C. albicans*), and *Aspergillus* sp. in different culture media over 7–21 days, with *Staphylococcus* sp. decrease starting on day 3 [71]. Several authors have advocated the use of silicone oil in the treatment of acute endophthalmitis as an adjunct to vitrectomy and intravitreal antibiotics, even in the absence of retinal detachment [72–80]. Kaynak et al. found no significant difference between the use of silicone oil as an adjunct or not on final VA, but the group that had silicone oil had less surgical procedures at the final follow-up [81].

One of the concerns of using silicone oil in the treatment of endophthalmitis is the theory of entrapment of inflammatory debris, as vitrectomy is incomplete in most cases of endophthalmitis, and antibiotics against the retina in the silicone-retina interface increase the chance of retinal toxicity or precipitation and limited activity [82]. A concern with the placement of an encircling band and silicone oil, used by Kaynak et al., is the increased risk of explant infection or extrusion/intrusion through the inflamed conjunctiva and sclera.

10.3.3.5 Adjunctive Therapies

Intravitreal Steroids

In the EVS, subconjunctival and intravitreal corticosteroids were used as adjuncts to treatments to reduce intraocular inflammation as intraocular damage is caused by the inflammatory response to infection [2]. The use of corticosteroids in such cases is an accepted practice. In an experimental model of infectious endophthalmitis, the use of triamcinolone acetonide 4 mg appeared to be safe and suppressed intraocular inflammation without affecting antibiotics' function [83]. The effect of intravitreal dexamethasone on intravitreal antibiotics appears to be safe in the treatment of infectious endophthalmitis but had no effect on final VA [84–87]. The use of intravitreal dexamethasone is strongly recommended in cases where oral prednisone is contraindicated. When

indicated, the authors prefer to use dexamethasone rather than triamcinolone due to its stronger effect and no added opacities in the opaque vitreous.

Tissue Plasminogen Activator (tPA)

Tissue plasminogen activator has been used for various indications, but there is no proof of benefit in using it in cases of endophthalmitis. In one series, there was resolution of posterior synechiae and increased pupil size [88]. Some of the feared complications are hyphema and increased IOP. This method does not seem to be a common practice by many retinal surgeons.

Antibiotics

Ceftazidime has largely replaced amikacin due to its superior safety profile. This is due to a concern about the risk of macular infarction secondary to aminoglycosides [27, 82, 89]. The coverage against gram-negative bacteria between both classes of antibiotics is comparable. Concerns about the concomitant use of vancomycin and ceftazidime were that together they might form precipitates that affect their activity [90, 91]. In an experimental study on the combination of vancomycin and ceftazidime, the latter was found to precipitate at body temperature regardless of the presence of vancomycin; normal saline was a better preparation media than BSS with a lower risk of precipitation [91]. Raju et al. showed that vancomycin was found to precipitate regardless of ceftazidime, but this did not seem to affect its antimicrobial activity [92]. The authors concluded that both drugs are compatible. Ciprofloxacin, a fluoroquinolone with a good gram-negative coverage, has been used as an intravitreal injection (0.1 mg/0.1 ml) as it has lower rates of precipitate formation [93, 94], but there is concern about emergence of resistant strains of bacteria [3, 17, 95]. A newer fourth-generation fluoroquinolone, moxifloxacin, demonstrated good vitreal therapeutic levels when administered orally, but its efficacy in endophthalmitis has not been widely proven yet [95, 96]. Intracameral or intravitreal moxifloxacin is another option in prophylaxis or treatment of endophthalmitis, and their role may increase as more literature becomes available [97–103].

Subconjunctival antibiotics, also used in EVS, were not found to be as beneficial as believed to be [104, 105], and their use has decreased significantly since the EVS [106].

Voriconazole is a potent antifungal agent with almost 100 % in vitro susceptibility profiles of *Candida*, *Aspergillus*, and *Fusarium*. It was also shown in vitro to be safe for intraocular administration at therapeutic levels below 250 micrograms/ml (mcg/ml) and to have excellent therapeutic intraocular levels after oral administration [107–109]. Intravitreal voriconazole (25 mcg/0.1 ml) was shown to successfully treat exogenous fungal endophthalmitis due to *Candida* or *Aspergillus* sp. with no reported adverse effects [110, 111]. Endogenous *Candida* endophthalmitis has been successfully treated using intravenous caspofungin and oral voriconazole [110]. The authors recommend the use of voriconazole 100 μg/0.1 ml for intravitreal injection to treat fungal endophthalmitis rather than amphotericin B 5 μg/0.1 ml due to the very limited safety profile and lower coverage spectrum of the latter. One important disadvantage of voriconazole is the high cost.

Summary for the Surgeon

- Due to its antimicrobial activity, some surgeons have advocated silicone oil use as an adjunct to the treatment of infectious endophthalmitis even in the absence of retinal detachment.
- Tissue plasminogen activator, to treat fibrin, has not gained enough support and popularity among retina surgeons.
- Intravitreal steroid benefits are controversial, but they may have a role in patients with systemic diseases where oral prednisone is contraindicated.
- Ceftazidime has largely replaced amikacin for gram-negative coverage, while vancomycin is still the drug of choice for gram-positive coverage.
- The use of subconjunctival antibiotics, as an adjunct to intravitreal antibiotics, has greatly regressed due to its questionable role.
- Intravitreal voriconazole 25–100 mcg/0.1 ml is a safe and effective treatment for fungal endophthalmitis.

10.3.3.6 Bleb-Associated Endophthalmitis

Bleb-associated endophthalmitis, as mentioned previously, tends to be more aggressive than post-cataract or secondary IOL implantation endophthalmitis, and the results of the EVS cannot be applied to these cases. There is a general consensus among retina specialists that early vitrectomy is preferred over tap and inject in such cases. The surgical procedure is essentially similar to the above mentioned one; the differences lie in the management of the bleb and conjunctiva. Sclerotomies should be positioned away from the bleb and the surrounding friable conjunctiva in order to avoid a possibly thinned sclera and tearing the conjunctiva, thus rendering wound closure more complicated. The bleb should be examined carefully for evidence of leakage, melting, and pus collection. In case of leakage or melting, the conjunctiva should be advanced, or the sclera should be closed using 6-0/7-0 Vicryl or with a scleral patch graft; this is best done at the beginning of the case to avoid dealing with a swollen conjunctiva due to infiltration of balanced salt solution during the case and to have a more stable IOP during surgery. If there is an obvious abscess, it should be excised and sent to pathology/microbiology, and the defect repaired accordingly. The conjunctiva should be manipulated gently, to avoid tearing it, and examined for dehiscence. Aiming toward water-tight closure at the conclusion of surgery should reduce the risk of reinfection.

10.3.3.7 Chronic Postoperative Endophthalmitis

The surgical procedure of choice for this specific entity is pars plana vitrectomy, total capsulectomy, IOL extraction or exchange, and intravitreal antibiotic; the rate of recurrence, as mentioned above, was reported to be 0 % [22, 30]. The following is a description of this procedure using 25-g MIVS:

- Create an inferotemporal 25-g transconjunctival scleral tunnel 3.0–3.5 mm posterior to the limbus and connect the infusion line; this should be turned off during the actual extraction of the IOL.
- Create two more 25-g transconjunctival scleral tunnels in the superonasal and superotemporal quadrants at 3.0–3.5 mm and place plugs in both cannulas or use the valved cannulas. At this point, it is better to turn off the infusion line to perform the anterior chamber work, as this will prevent prolapse of the viscoelastic material and anterior segment structures.
- If the pupil is not sufficiently dilated, use any option of mechanical pupil dilators to better expose the capsule and zonules. The authors prefer to place iris hooks. Start by using a bent 26-g needle placed on a dispersive viscoelastic syringe to create four to five paracenteses. This helps to dissect any posterior synechiae and to maintain the AC volume while placing the iris hooks.
- Create a 2.75-mm two-plane clear corneal incision superiorly. Avoid using an old incision as this increases the risk of post-op infection [6]. Remember to always examine the old wound; if in doubt of its integrity, place a 10-0 nylon suture.
- Using two Sinskey hooks, examine the IOL in the bag to check if the IOL is free and mobile or if they are both fused together.

In Cases When IOL Is Mobile (Fig. 10.18)

- Inject viscoelastic into the bag and then, using the two hooks, rotate the IOL into the anterior chamber.
- Going through the main corneal wound, stabilize the IOL using the IOL forceps and then cut it in the middle of its optic using the IOL scissors to about three-fourths of its length and remove it in one piece through the main corneal wound.
- If the eye becomes too soft during the IOL extraction, the infusion line can be unclamped intermittently to restore IOP.
- Turn on the infusion line and unplug the superonasal cannula.
- Introduce the MAXGRIP forceps (Alcon Labs, Fort Worth, TX, USA) through the side port, grab the capsular bag and pull to expose the zonules and then use the vitrector through the *pars plana* to cut them at 360 degrees. Once completely freed, remove the IOL through the main corneal wound.
- Secure the superior corneal wound using 10-0 nylon.

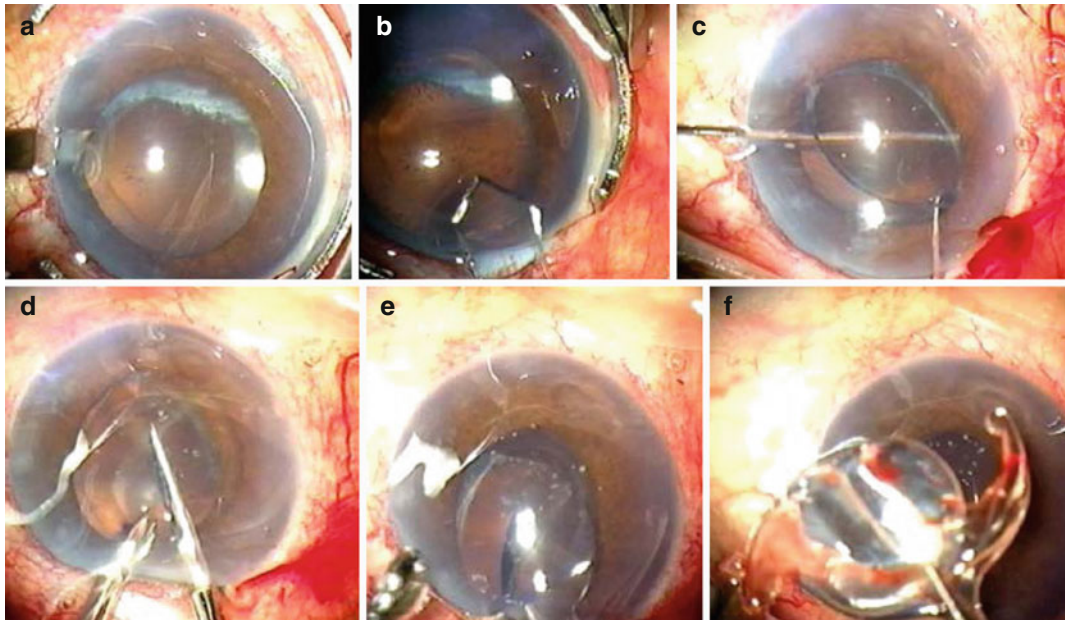

Fig. 10.18 Chronic post-op endophthalmitis. (**a**) A 1.2-mm side port is created. (**b**) A 3.2-mm main incision is done after viscoelastic insertion through the side port. (**c**) Intraocular lens (IOL) is explanted from the capsular bag. (**d**) An intraocular forceps is used to grasp the IOL, and an intraocular scissors is used to cut the IOL. (**e**) The one-piece IOL is removed without enlarging the clear corneal wound. (**f**) Cut IOL removed (Source: Rezende and Kickinger. Infectious Endophthalmitis. Essentials of Opthalmology, Vitreo-retinal Surgery Progress 3)

In Cases When the Capsule and IOL Are Fused Together (Fig. 10.19)

- Keep the infusion open and unplug the superonasal cannula (away from the corneal side port).
- Introduce the MAXGRIP forceps (Alcon Labs, Fort Worth, TX, USA) through the side port into the AC and grab the lens-bag complex to pull to one side to expose the zonules. Then, cut the zonules 360° using the vitrector through the *pars plana* 25-g cannula without releasing the lens-bag complex.
- After the complex is completely free, place it into the anterior chamber, making sure it stays stable over the iris.
- Next, place a plug on the open cannula (in case no valved cannula is available) and turn off the infusion.
- The rest of the steps to extract the IOL-bag complex are as mentioned above.
- The lens and bag should both be sent for gram staining and direct inoculation onto bacterial and fungal cultures; at least two anaerobic cultures should be used (thioglycolate broth and CDC anaerobic blood agar).
- Next, perform core vitrectomy under a wide-angle noncontact viewing system to avoid corneal abrasions on an infected eye. Usually, the media clarity is good and will allow you to detach the posterior vitreous and shave the anterior vitreous base. Some of the endocapsular hypopyon could fall back onto the retina while manipulating the capsular bag. This could be cautiously removed with a soft-tip extrusion cannula.
- Examine the vitreous base for any remaining hypopyon or retinal breaks due to the manipulation that was performed. This could be done with scleral depression under the microscope or wide-angle viewing system.
- At the conclusion of vitrectomy, remove all viscoelastic material from the AC and follow the same steps mentioned above to remove the cannulas.

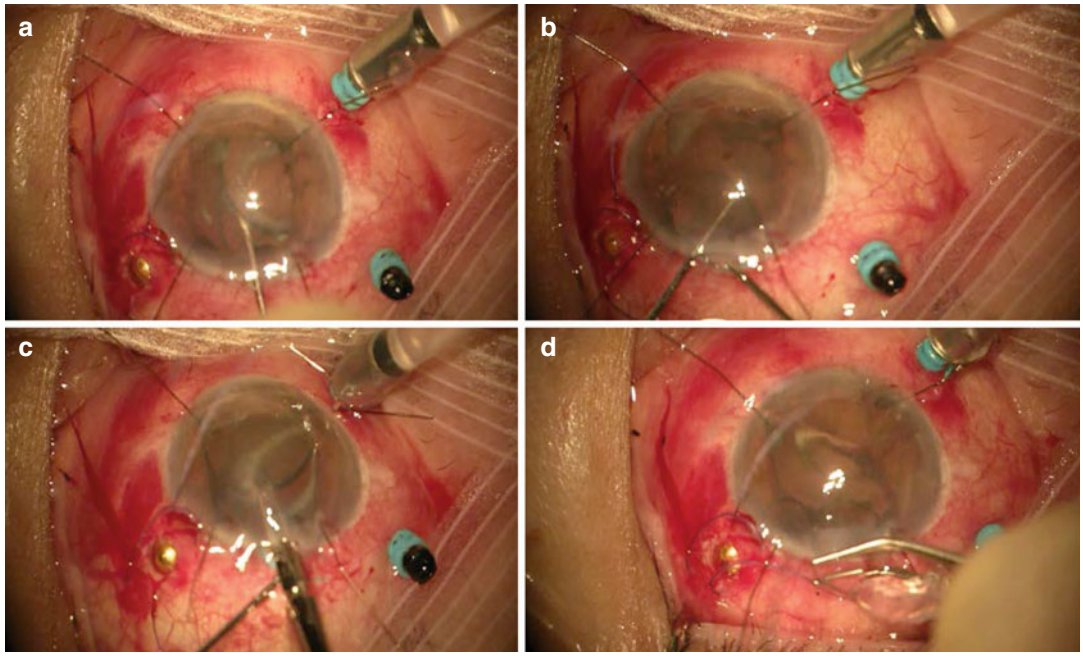

Fig. 10.19 Chronic post-op endophthalmitis with IOL and bag fused together. (**a**) Dissecting the IOL-bag complex using 26-g needle mounted on the viscoelastic syringe. (**b**) A Sinskey hook was used to complete the dissection from the zonules bimanually while stabilizing the IOL using a MAXGRIP forceps (Alcon Labs, Fort Worth, TX, USA). (**c**) The complex secured on top of the pupil and the optic being cut in its midline to three-fourths of its diameter. (**d**) Extracting the complex through a 2.75-mm clear corneal incision using intraocular forceps followed by McPherson curved tying forceps

- Inject intravitreal vancomycin 1 mg/0.1 ml (most common organisms are *P. acnes* and *S. epidermidis*). If a fungal infection is suspected, intravitreal voriconazole 100 μm/0.1 ml should be injected at the end. The vitrectomy cassette should also be sent for gram staining and cultures.

Comments

The eye could be left aphakic until the endophthalmitis resolves, and a secondary IOL implantation would be planned at that point (Fig. 10.20). The rate of recurrence in the reported series was 0 % with either immediate or delayed IOL implantation.

The authors recommend, when available, to place an endoscope through the *pars plana* to examine the anterior retina, the ciliary body, and the posterior surface of the iris for any remaining abscess or fibrosis that may result in post-op complications.

10.3.3.8 Post-vitrectomy Endophthalmitis

In recent retrospective reviews [112–114], meta-analysis by Bahrani et al. [60], and a report on small-gauge *pars plana* vitrectomy by Recchia et al. [115], the incidence of endophthalmitis in specific and other post-op complications in general was not statistically significant when comparing 20-g versus 25-g vitrectomy. Endophthalmitis rates were found to range between 0.0278 % and 0.076 % post-20-g vitrectomy versus 0.0299–0.07 % post-25-g vitrectomy. If endophthalmitis does occur, it seems to have poor VA outcomes when compared to cases in the EVS or post-intravitreal injection [116, 117]. In a 20-year review of post-vitrectomy endophthalmitis (1984–2003) report from the Bascom Palmer Eye Institute, final VA after treatment ranged from 20/200 to no light perception, with final VA of light perception or no light perception in four of six eyes

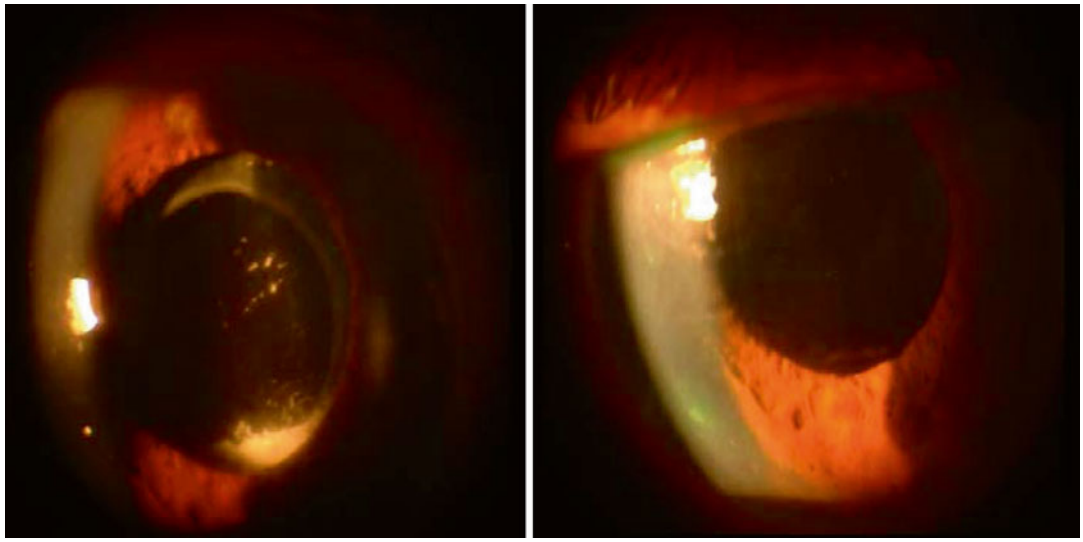

Fig. 10.20 Chronic postoperative *Propionibacterium acnes* endophthalmitis. Preoperative biomicroscopy image of endocapsular hypopyon (*left*). One month postoperative, the eye was left aphakic and the patient regained useful vision (*right*) (Source: Rezende and Kickinger. Infectious Endophthalmitis. Essentials of Opthalmology, Vitreo-retinal surgery progress 3)

(67 %) [116, 118]. In another review by Scott et al. of endophthalmitis after 25g versus 20g, 11 cases developed endophthalmitis post-25-g vitrectomy. Six grew *S. epidermidis*, one grew *Enterococcus*, three had no growth, and one had no culture specimen. Out of 11 patients, 73 % (8 patients) had final VA of 20/400 or better and 36 % (4 patients) had final VA of 20/63 or better [119]. There is no consensus on the best treatment option for post-vitrectomy endophthalmitis, but as it tends to have worse outcomes, the authors prefer vitrectomy with intravitreal antibiotics over tap and inject [119].

10.3.3.9 Post-Boston Keratoprosthesis Endophthalmitis

The prevalence of KPE is higher than most surgical procedures, reported as high as 12.5 % in one series. The presentation is usually beyond 6 weeks post-op [52]. There should be a high index of suspicion in any case of vitritis, retrolenticular membrane, or decreased vision, as pain is not always present and vitreous samples yield is not always positive [52, 55, 120]. Vitrectomy with intravitreal antibiotics is usually the preferred procedure, as these cases tend to be more severe with poor visual outcomes [54, 55]. Either MIVS using a wide-angle noncontact viewing system or endoscopy-guided MIVS could be indicated. Anterior chamber samples' yield was 0 % in one series [55], so they should usually be avoided. It is important to look for corneal or scleral melting, and treatment should be adjusted accordingly in association with a cornea specialist. The most important post-op prophylactic measure is vancomycin drops in addition to the routine quinolone drops. In a series by Ramchandran et al., all ten patients that were diagnosed with PKE had had stopped the vancomycin drops for a short period before the infection developed, and three eyes had recurrent endophthalmitis after stopping the prophylactic drops [55].

On the other hand, not all cases of vitritis without pain or conjunctival injection should be considered as endophthalmitis. In the same review of PKE cases by Ramchandran et al., there were seven eyes that had painless vitritis with no injection and were treated successfully with sub-Tenon's steroid injection without recurrence [55]. In another series by Nouri et al.,

Table 10.2 Pre- and post-op visual acuities and culture results of 11 post-cataract endophthalmitis cases

Patient	Gender	Preoperative visual acuity	Postoperative visual acuity	Culture result
1	Female	Light perception	20/400	*S. epidermidis*
2	Female	Light perception	20/80	No growth
3	Male	Light perception	Counting fingers	*S. epidermidis*
4	Female	Light perception	Hand motion	*Haemophilus* sp.
5	Female	Light perception	Counting fingers	*Streptococcus* sp.
6	Male	Light perception	20/40	No growth
7	Female	Light perception	20/400	*Streptococcus* sp.
8	Male	Light perception	Counting fingers	*S. epidermidis*
9	Male	Light perception	Hand motion	*S. epidermidis*
10	Female	Light perception	20/25	No growth
11	Male	Light perception	Hand motion	*Haemophilus* sp.

Source: Rezende and Kickinger. Infectious Endophthalmitis. Essentials of Opthalmology, Vitreo-retinal surgery progress 3

three patients with isolated vitritis were successfully treated with topical steroids only, and the authors believe that it was due to overnight eye rubbing and release of necrotic material into the AC [54].

10.3.4 MIVS Safety and Surgical Results

The safety of MIVS compared to 20-g vitrectomy was a major concern for many surgeons. In two large series, the incidence of post-vitrectomy endophthalmitis was found to be significantly higher after 25 gauge compared to 20 gauge [117, 119]. Kunimoto et al. found the rate to be 1 in 5,498 eyes after 20-gauge vitrectomy (0.018 %) and in 7 of 3,103 eyes after 25-gauge MIVS (0.23 %). Scott et al. found the rate to be 2 cases per 6,375 patients (or 1 in 3,188; 0.03 %) after 20-gauge MIVS compared with 11 cases per 1,307 patients (or 1 in 119, 0.084 %) after 25-gauge MIVS. More recent reviews and meta-analysis have shown the safety of MIVS, and it is now acceptable as the procedure of choice in many centers [60, 112, 115, 121].

Rezende et al. conducted a prospective non-comparative series of post-cataract endophthalmitis cases that were treated using MIVS (Table 10.2). There were 11 eyes of 11 patients that presented within 6 weeks of surgery (mean 7 days). One patient had inferior retinal necrosis and intra-op RD treated by laser photocoagulation and silicone oil. Three out of 11 vitreous samples had no growth. None of the patients had serious post-op complications, including RD and *phthisis bulbi*. Using the 25-g vitrector, 73 % positive culture samples were obtained compared to 73.5 % with 20g during the EVS, 63 % with total vitrectomy, and 100 % with vitrectomy and endoscopy [122].

The advantages of MIVS over 20 gauge for infectious endophthalmitis management include less manipulation of the conjunctiva with less discomfort for the patient, less ocular surface bleeding, finer instruments, a more controlled intraocular fluidics, and ability to perform more precise intraocular maneuvers with less trauma to tissues.

Several factors could increase the risk of post-MIVS endophthalmitis including scleral tunnel construction, air or gas tamponade, the amount of vitreous left behind, conjunctival displacement, and post-op hypotony [60, 115, 121, 123]. Certain surgical techniques and steps are important to reduce this risk. The wound has to be structured as a tunnel rather than a straight entry; this was shown to form better self-sealing wounds with lower incidence of vitreous incarceration or conjunctival bleb formation [70, 121–126]. The newer generation of trocars is designed to form a slit-like sclerotomy rather than a semilunar

(smiley face), and this is believed to separate more scleral fibers than cutting them and to be better self-sealing than older generations. Flattening the sclera while displacing the conjunctiva using an angled McPherson forceps helps in obtaining a longer tract for the scleral tunnel. Air/gas tamponade at the conclusion of surgery aids in sealing off the sclerotomies internally and prevents post-op hypotony [115, 121], but there are concerns about increasing the antibiotics concentration in a partially filled cavity [127], and some authors suggest reducing antibiotics concentrations in such cases [128].

Conclusion

In summary, MIVS seems to be a safe and effective procedure and comparable to other available techniques to manage infectious endophthalmitis. The smaller size of the instruments allows for more meticulous surgery and is more comfortable for patients with already severely inflamed eyes. Using endoscopy-guided MIVS for the management of endophthalmitis has the advantages of bypassing the opaque anterior segment and allows for a more thorough vitrectomy and a better evaluation of the posterior pole, the anterior retina, and the ciliary body and management of concurrent pathologies that would be otherwise very difficult to manage under the limited conventional microscope viewing systems.

In our opinion, MIVS should be considered as a first line of choice for the surgical management of infectious endophthalmitis. Further studies with larger samples are needed to confirm our results.

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Vitreoretinal Endoscopy

11

Flavio A. Rezende, Thiran Jayasundera, Thomas Lee, Kyle V. Marra, and Jorge G. Arroyo

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F.A. Rezende, MD, PhD (✉)
Department of Ophthalmology, Maisonneuve-Rosemont Hospital, Blainville, QC, CANADA
e-mail: frezendef@hotmail.com

T. Jayasundera • T. Lee • K.V. Marra • J.G. Arroyo
Organisation Name, City, Country

11.1 Introduction

The first ocular endoscopy surgery dates as far back as 1934, when a rudimentary form of an endoscope was used for removal of intravitreal foreign bodies [54]. Thereafter, the retina community was unhurried to further develop and adopt the techniques of endoscopy, which rapidly became the mainstay of interventional medical and surgical specialties in the 1990s. However, there has been a recent surge in the use of vitreoretinal endoscopy as technology has advanced to give surgeons higher-resolution imaging and as it has been speedily adopted by glaucoma surgeons for successfully performing endocyclophotocoagulation (ECP). This technology has been particularly advantageous in pediatric retinal surgery.

In adult vitreoretinal surgery, there is no longer a necessity to perform "blind" vitrectomies for patients with media opacity in the scenarios of endophthalmitis (addressed in a separate chapter) (especially in penetrating trauma) or in pars plana glaucoma tube insertion for patients with refractory glaucoma. In these settings where surgery needs to occur relatively quickly, corneal grafting surgery may not be possible due to the lack of donor tissue or the availability of an anterior segment surgeon (especially in a private practice setting) and may also not be optimal for longevity of graft survival. The ability to visualize the pars plana, ciliary processes, and retroirideal

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space may be beneficial in certain cases with anterior fibrovascular proliferation causing recurrent vitreous hemorrhages and cyclitic membranes causing hypotony. The inability to optimally visualize these areas and address pathology with conventional endoillumination-based vitrectomy techniques can be overcome by the use of an endoscope. Ciadella et al. found endoscopic visualization of the retroirideal space, a useful technique for the successful treatment of cases with recurrent vitreous hemorrhage from proliferative diabetic retinopathy (PDR) [59].

In this chapter, vitreoretinal surgeons will describe their experience and share tips with performing endoscopy-guided pars plana vitrectomies. The indications for its use in cases with PDR and neovascular glaucoma, anterior segment disease, primary rhegmatogenous retinal detachment (RD), tractional retinal detachments requiring retinectomy, ciliary body detachments leading to hypotony, intraocular foreign bodies, and pediatric indications will be discussed. Current usage of small-gauge endoscopy will also be addressed. Contemplations in future technological developments to further aid the vitreoretinal surgeon will energize the retina community to expand the use of endoscopic techniques.

11.2 Learning Curve

Utilizing the endoscope within the realm of vitreoretinal surgery is challenging and initially associated with a relatively steep learning curve. One of the biggest challenges of endoscopy lies in its lack of binocular stereopsis. There are a number of techniques available that facilitate the adoption of the endoscope-assisted vitrectomy into the vitreoretinal practice. The efforts spent becoming more comfortable and more adept using the endoscope during surgery will significantly expand the breadth of complicated case the retinal surgeon is able to address.

Ophthalmic surgeons are most comfortable with and used to visualizing the eyes through an operating room binocular surgical microscope. The point of view is relatively fixed in most cases allowing the surgeon to operate bimanually on or in the eye. In contrast, visualization through a monocular endoscope, by design, provides multiple axial points of view depending where in the eye the endoscope tip is positioned. Furthermore, in any given position within the eye, rotation of the endoscope itself will result in rotation of the image viewed, and any resultant disorientation may be compounded by resolute high magnification. Therefore, both moving the endoscope tip into a position that optimize the view and working with an instrument in the second hand visualized through the endoscope provide two levels of complexity in the adoption of endoscopy in routine vitreoretinal surgery.

First important step is placing the endoscope screen in a position that the surgeon does not need to turn his/her head too much to look at it (Fig. 11.1). Otherwise your neck can become quite stiff during long cases. Finding a position for the screen where your neck is not turned and such that neither your assistant nor your scrub nurses are on your way is key before entering the eye. During the cases, you can always ask the circulating nurses to readjust focus, light intensity, and orientation on the screen. Unfortunately, the surgeons do not control these parameters on the foot pedal (only the endolaser is controlled by the pedal).

Focusing the endoscope and determining what is superior and inferior on the monitor screen prior to its introduction into the globe through the sclerotomy can more quickly familiarize the surgeon with controlling the orientation of the intraoperative view, which is crucial for navigating the posterior segment (Fig. 11.2). Since the light source and camera are in the same axis, shadowing is also eliminated and awareness of instruments' location within the globe therefore relies on monocular clues such as the size of landmarks, intensity of illumination, and changes in focus. Exploring the posterior pole is learned more quickly because of its distinct landmarks and intuitive maneuvering, while viewing anteriorly may require additional learning time.

Orientation inside the eye is probably the most challenging step in learning vitreoretinal endoscopy. The image on the screen can be turned either by turning the endoscopy probe on the

Fig. 11.1 Room setup. (**a**) Endoscopy unit placed on the opposite side of the surgical microscope in relation to the patient's bed. The setup should allow the surgeon to quickly switch from the endoscopic view to the microscope view without having to turn much his/her head (**b**, **c**)

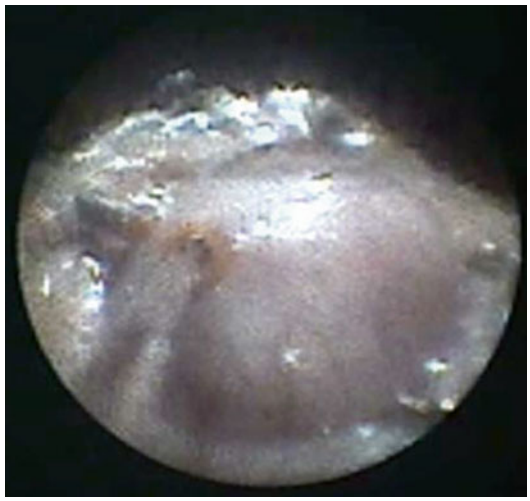

Fig. 11.2 Focusing the endoscopic image prior to entering the eye. Note fluid coming out of the 23-gauge cannula (slight *left*)

surgeon's hand or by the circulating nurse turning on the orientation knob at the endoscopy console (Fig. 11.3). For this particular reason, we prefer to use the straight probe rather than the curved one (used mostly for endocyclophotocoagulation through the anterior segment of the eye).

One of the best ways to overcome some of these challenges is initially separate endoscopic visualization from visualization and use of an instrument in the second hand. Using either the 20-gauge or 23-gauge endoscopy probes, the surgeon should initially use the endoscope primarily for illumination and endolaser during routine vitreoretinal cases. These are both steps that the vitreoretinal surgeon is already comfortable performing with a light pipe and endolaser probe. During these cases, the surgeon can quickly switch from the microscopic view to the endoscopic view in order to get used to the manipulation of the endoscopic probe and become more accustomed with visualization through the endoscope. Although the view is somewhat limited through the smaller diameter probe, the 23-gauge endoscope probe increases the ease of use during 23-gauge surgery cases because one can switch the probe from one trocar to another for better visualization of certain areas. But for the first cases, we recommend using the larger probes (19 gauge or 20 gauge) because of its better resolution and illumination capabilities.

The next level of complexity for the surgeon would include beginning to perform endoscopic retinal laser photocoagulation treatment and endoscopic cyclophotocoagulation treatment. The surgeon needs to control the distance of the probe tip from the retina or ciliary body, the power of the laser setting, and the duration of exposure. Utilizing the endoscopic laser for both retinal photocoagulation and cyclophotocoagulation treatment further increases the comfort level with the endoscopic system. Typically, a power intensity of 0.6 W is utilized for retinal laser, and 0.35 W is utilized for endoscopic cyclophotocoagulation treatment.

Once the surgeon has become familiarized with positioning of the endoscope within the eye and viewing in the eye through the endoscope, the surgeon can then introduce an instrument with the second hand that can be operated under direct endoscopic visualization. Some examples of cases where this may be applied are peripheral vitreous base dissections using the vitreous cutter

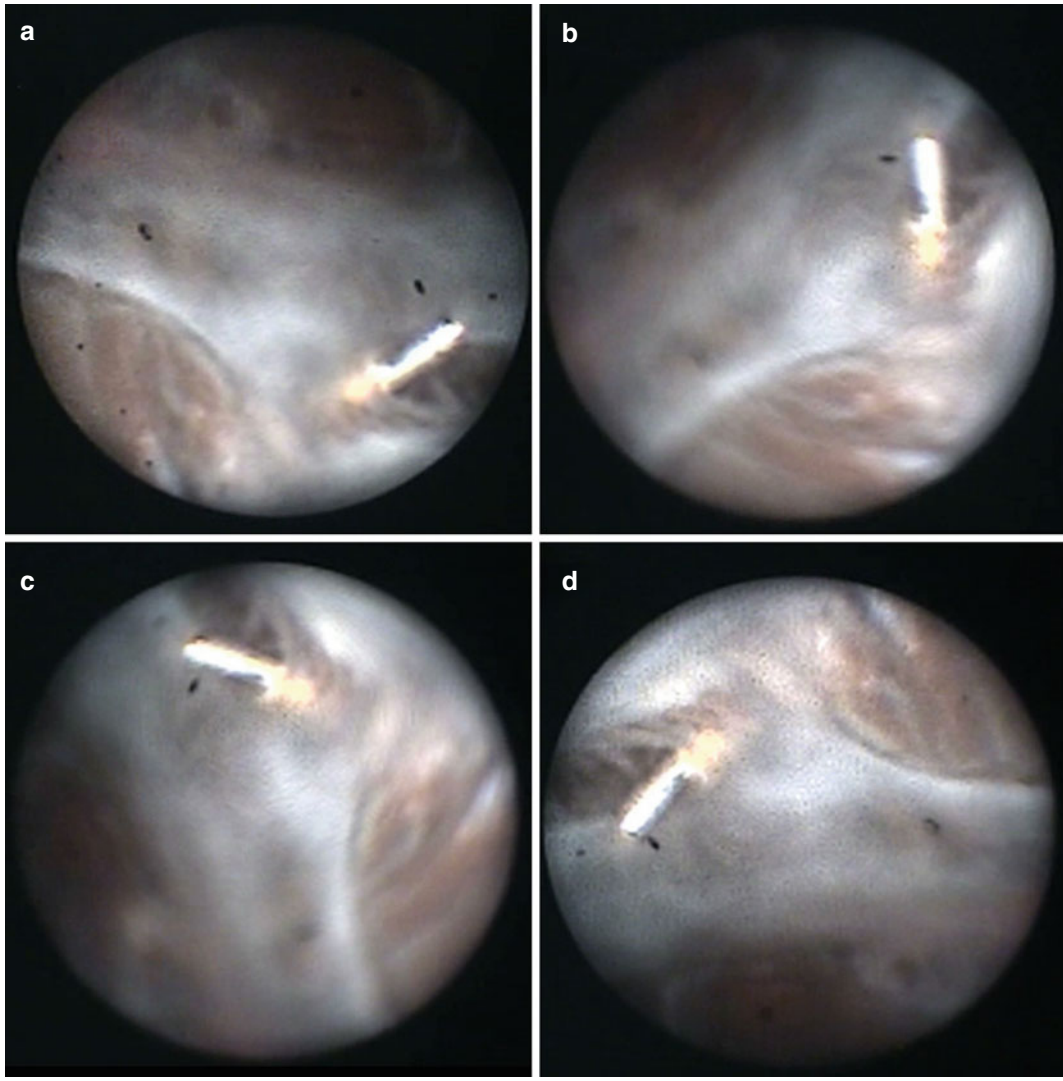

Fig. 11.3 Endoscopic orientation. The surgeon can turn the image at his convenience either by turning the endoscope probe on its hand or asking the nurse to turn the focusing/orientation knob on the endoscopy console. Note that on (**a**), the 25-gauge cannula is inferior. The image was turned to place the cannula on the superior part of the screen (**d**)

and removal of the capsule from the ciliary processes after pars plana lensectomy using endgrasping forceps.

In cases of clear media, the surgeon can always switch from looking at the screen to looking through the microscope if one becomes disoriented and it helps repositioning your hands and instruments accordingly.

Another exercise that helps understanding the advantages of using endoscopy for peripheral work at anterior retina or ciliary body is flipping from endoscopy to a wide-angle viewing system using scleral depression. Only with time surgeons will appreciate the level of additional benefits you can get using endoscopy to access this region of the globe.

Without a doubt, the efforts spent by a surgeon to become more familiarized and comfortable with the ophthalmic endoscope will pay dividends in more challenging vitreoretinal cases.

It should become part of the regular vitreoretinal armamentarium in operating rooms worldwide. For additional information, a basic teaching video is available at http://www.youtube.com/watch?v=n3R1a9SeB8o.

11.3 Small-Gauge Endoscopy

Although a 23-gauge endoscopy probe was introduced in 2008 (OME 230 LA, Endo Optiks, Little Silver, NJ, USA) and a triple-function (video, illumination, and laser) probe has been commercially available in North America since 2011 (OME 230 SMA EA, Endo Optiks, Little Silver, NJ, USA), very little literature is published on this subject [25]. It allows the visualization of the posterior pole up to the ciliary processes and all the way to the posterior surface of the iris, depending on where the surgeon is aiming the probe, the same way as the larger 19/20 g probes do.

There are a few benefits of the small-gauge probe over the larger ones. Because of its reduced diameter (0.56 mm), it fits inside the standard 23-gauge cannulas (Fig. 11.4). This way you can alternate the view provided by this probe by switching hands and using it in any of the three 23-gauge cannulas for better access of the extreme retinal periphery and ciliary body for a more complete removal of all anteriorly located fibrotic membranes or better visibility of both intraocular lens haptics to determine its proper position in the ciliary sulcus. The surgeon can even rotate its seating position from superior to temporal and switch the infusion line from inferotemporal to supero-nasal to allow better access to tissues located around the 12 o'clock meridian. Switching the 23-gauge endoscope probe from one port to another may also allow a more thorough vitreous shaving around the cannula sites.

When used through the 23-gauge valved cannula systems, it also allows for a much better fluidics control during complicated membrane peeling that often can result in bleeding. Hemostasis is much easier in close chamber environment working only through valved cannulas rather than larger gauge leaky incisions without cannulas.

Another important aspect is that you can use in all complicated indications as you would with the larger probes. This is important because after you passed through the learning curve, you can use exclusively 23-gauge probes without much compromise.

For obtaining a better image on the screen when using the 23-gauge endoprobe, although not required, you can have a stronger 300-W xenon light source (standard is 175 W) and a specific adapter for image magnification (600ZMG, Endo Optiks, Little Silver, NJ, USA).

The limitations of this small-gauge probe include the significantly lower resolution of 6,000 pixels (compared to 17,000 pixels on the high-resolution larger probes) and a narrower field of view of 90° (rather than 140° on the

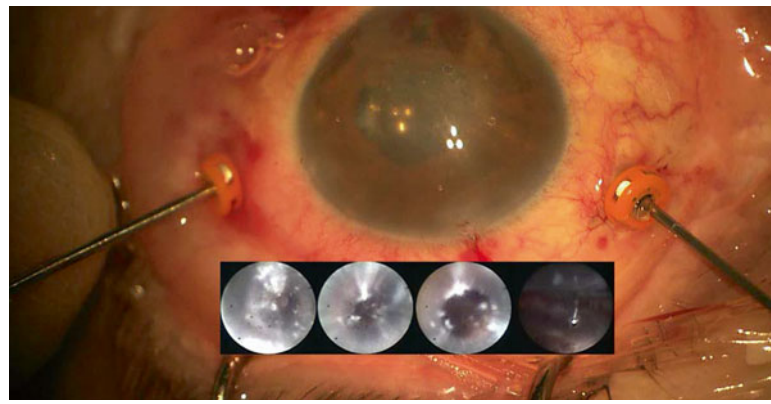

Fig. 11.4 23-gauge endoscopy probe (*left* trocar) and 23-gauge vitrector probe (*right*) under microscope visualization. Note the sequence of endoscopic view progressing inside the valved 23-gauge cannula until reaching the vitreous cavity (*bottom*)

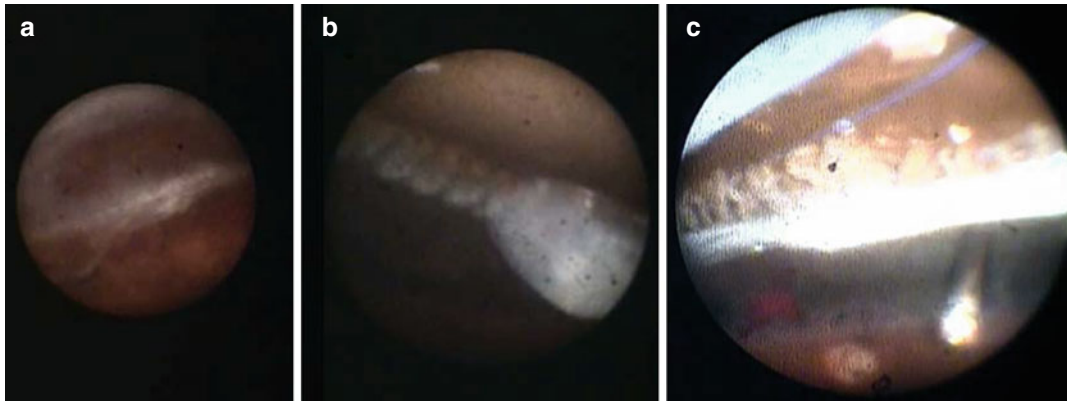

Fig. 11.5 (**a**) Endoscopic image of severe anterior proliferative vitreoretinopathy with the 23-gauge endoscope with the standard adapter (300ZMG, Endo Optiks, Little Silver, NJ, USA). (**b**) 23-gauge endoscope image of residual nuclear material under the iris in traumatic subluxated cataract. Note that the image is almost double the size with the proper 23-gauge adapter (600ZMG, Endo Optiks, Little Silver, NJ, USA); (**c**) 19-gauge endoscopic high-resolution image of an intraocular lens (IOL) placed in the sulcus in a case of dropped IOL during previous cataract surgery

19/20 g probes) (Fig. 11.5) [33]. For these reasons, we recommend the smaller-gauge endoscopy probe only for more experienced surgeons used to vitreoretinal endoscopic surgery.

11.4 Adult Complex Vitreoretinal Cases Indications

11.4.1 Proliferative Diabetic Retinopathy and Neovascular Glaucoma

The endoscope is a valuable ophthalmic instrument that provides a unique and variable perspective into the posterior segment of the eye. This "third eye" view into the vitreous cavity facilitates the treatment of proliferative diabetic retinopathy with anterior pathology such as anterior hyloidal fibrovascular proliferation, fibrovascular ingrowth post-vitrectomies, cases of neovascular glaucoma due to any of the ischemic retinopathies, and placement of pars plana tube shunt (http://www.youtube.com/watch?v=qY5nvKOM_SU).

11.4.1.1 Endoscopic Cyclophotocoagulation

Endoscopic cyclophotocoagulation is achieved using an intraocular endoscopy to directly visualize and photocoagulate the ciliary processes of the ciliary body in order to decrease aqueous production [18, 56]. In the past, cyclodestructive procedures have been used in the treatment of refractory glaucomas, [9] end-stage glaucomas, [2] or in combined surgeries with cataract extraction [20, 57]. The indications for ECP have expanded due to the endoscope's ability to apply mild laser burns to structures, such as the ciliary processes, that are difficult to visualize and treat using other available techniques.

To apply ECP during cataract surgery, the endoscopic probe is inserted transpupillary through the cataract wound. With the aid of a viscoelastic agent, the probe is positioned between the lens and iris. In this position, the endoscopic laser may be applied to about 8 clock hours of the anterior ciliary body. When the laser application is required in more than 8 clock hours, a second limbal wound must be created.

Following pars plana vitrectomy, the endoscope can also be introduced through the sclerotomy. This technique provides nearly full visualization of the ciliary processes, thus allowing for more comprehensive ECP treatment (Fig. 11.6). However, a second sclerotomy located 6 clock hours from the first port is needed in order to treat 12 clock hours with laser. Observational studies have been conducted on patients with neovascular glaucoma that received 12 clock hours of continuous endoscopic laser

treatment at 0.35 W [2]. These studies have shown excellent intraocular pressure control with a low rate of postoperative complications.

Vapor bubbles may form if a patient is heavily pigmented, if the laser power is too high, or if the probe is too close to the ciliary processes. This vapor occurs when aqueous is converted into steam. Preventing this vapor formation is a simple but learned technique. Lowering the laser power and/or distancing the probe from the ciliary processes can easily prevent this problem.

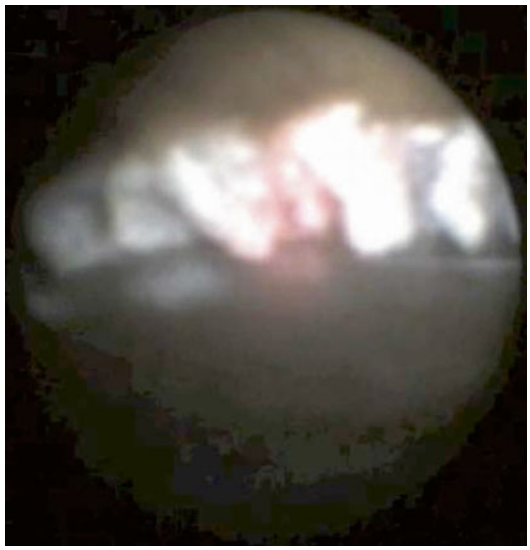

Fig. 11.6 Endoscopic ciliary body photocoagulation

11.4.1.2 Panretinal Photocoagulation (PRP)

When inserted through a pars plana sclerotomy, the endoscope allows for a 360° wide field of view of the peripheral retina. A full view of the retina allows for the extension of panretinal photocoagulation (PRP) from the equator out to the ora serrata, areas that are sometimes difficult to treat using standard endolaser techniques (Fig. 11.7). Visualization of the peripheral retina facilitates the thorough application of retinal photocoagulation in severe ischemic retinal vasculopathies. Since some surgeons may wish to avoid the possibility of significant laser burns from the endoscope's 810 nm diode, an argon laser attachment is available to provide familiar argon green wavelength treatment.

11.4.2 Cornea Opacities and Anterior Segment Disfiguration

The ophthalmic application of endoscopy has two fundamental advantages: (1) circumventing anterior segment opacities and (2) visualizing anterior structures like the ciliary body and sub-

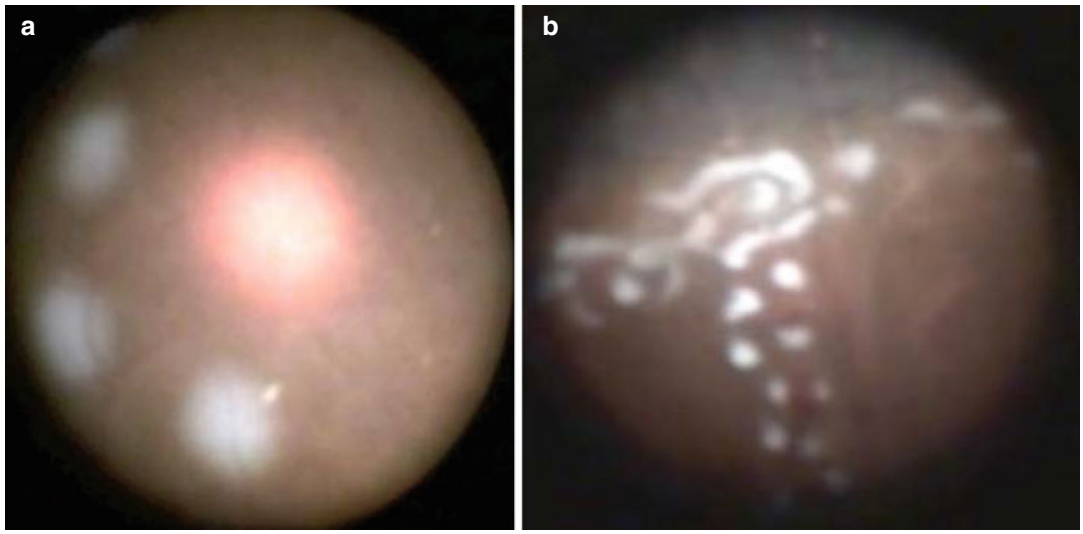

Fig. 11.7 (**a**) Endoscopic view of aiming beam during panretinal photocoagulation. (**b**) Note that the laser can be applied on the retinal periphery all the way to the ora serrata

iris space. Bypassing anterior segment opacities, endoscopy is a particularly powerful tool in cases where corneal edema or scarring blocks the standard microscopic view (Fig. 11.8). The endoscopic probe's flexibility allows for rapid changes in perspective and thus provides unique views of anterior structures. These planes of visualization are not available using the traditional techniques of microscopic vitrectomy [2]. The high magnification and wide field-of-view (ranging from 90 to 140°) offered by the endoscope not only increase the safety of surgical procedures but also facilitate the identification of subtle findings like small retinal breaks or holes.

11.4.2.1 Indication: Anterior Segment Opacities

Anterior segment opacities present a variety of obstacles during ophthalmic surgery. Unlike many other vitrectomy techniques, endoscopic vitrectomy remains possible despite anterior segment opacities. In fact, small studies report better visual and anatomical outcomes in eyes treated with endoscopy versus other surgical options using temporary keratoprosthesis to increase visualization [10].

Visualization for vitrectomy is significantly limited in cases when corneal opacities require penetrating keratoplasty or when intraoperative corneal edema progressively worsens the microscopic view (Fig. 11.8). Generally, this issue is addressed by one of the three treatment options: (1) observation of the posterior segment until corneal opacities clear to allow for uninhibited management, (2) combined surgery wherein implantation of a temporary keratoprosthesis allows for conventional pars plana vitrectomy and a permanent keratoplasty is implanted at the end of the case, or (3) [11] endoscope-assisted vitrectomy, which circumvents anterior segment opacities and may or may not require subsequent keratoplasty. The appropriate intervention plan

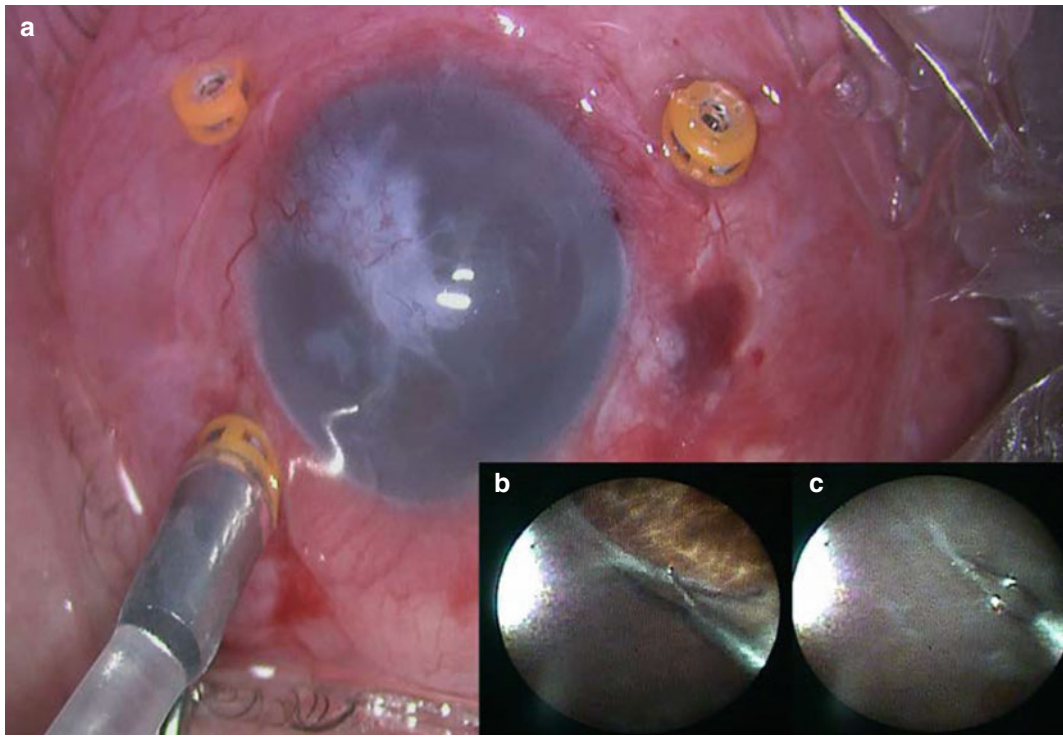

Fig. 11.8 (**a**) Central corneal scarring from previous penetrating wound. This eye underwent 23-gauge pars plana vitrectomy with endoscopic peeling of proliferative vitreoretinopathy (**b**) and epiretinal membrane (**c**) followed by penetrating keratoplasty, secondary intraocular lens implantation, and silicone oil tamponade

depends upon the urgency of posterior segment treatment and the prognosis and availability of a corneal graft. The obtainability of corneal grafts in the USA and Canada is a beneficial luxury; many other nations are not afforded the same convenience [48].

Temporary keratoprosthesis or endoscopy is advisable for urgent cases where observation of anterior segment opacities is unwise. Indications for these techniques include severe endophthalmitis, intraocular foreign bodies, and acute retinal detachment.

Since corneal grafts are not readily available in the majority of the world, the use of a temporary keratoprosthesis can be limited by its requirement of a graft after vitrectomy. In addition, temporary keratoprostheses may require coordination with corneal surgeons. Ocular conditions that preclude this modality include acutely injured globes with severely deformed anterior segments and underlying ocular surface diseases prone to graft failure such as severe autoimmune keratoconjunctivitis.

In addition to its more extensive list of applications, endoscopic vitrectomy has shown improved anatomical and visual outcomes in small retrospective studies. Chun, Coyler, and Wroblewski compared eight traumatic eyes treated with a vitrectomy aided by temporary keratoprosthesis to nine eyes that underwent endoscopic vitrectomy [10]. The outcome measures included time to surgery, surgical time, visual outcome, and a qualitative assessment of postoperative developments. Though the study's small sample size limits its statistical power, the report indicated that endoscopy cases had significantly shorter time to surgery (median 14 vs 38 days; $p = 0.034$) as well as significantly shorter surgical time (median 2.9 vs 8.4 h; $p < 0.0005$). Eyes treated with temporary keratoprosthesis prior to vitrectomy were observed more conservatively, causing a greater time lapse to occur before the decision was made to intervene with vitrectomy. With endoscopic vitrectomy as part of the armamentarium, surgeons may undertake vitreoretinal intervention without hesitation and with less concern for medical management of the anterior segment opacity.

In the above study by Chun et al., many occult retinal tears in the endoscopy group would have progressed to retinal detachment if observed conservatively. Instead, these tears were discovered and effectively treated. Furthermore, the group treated with endoscope-assisted vitrectomy had lower rates of advanced proliferative vitreoretinopathy (PVR) and postoperative retinal detachments, presumably due to its significantly shorter time to intervention and intraoperative detection of small retinal breaks. Conversely, the keratoprosthesis group had a greater number of cases where membrane peeling and perfluorocarbon were employed. The increased rate of membrane peeling and perfluorocarbon use may be attributed to proliferative vitreoretinal proliferation that may have occurred during the significantly greater time that lapsed prior to surgical intervention. The endoscopic group exhibited a trend towards better visual and anatomic outcomes, but this trend was not statistically significant.

11.4.2.2 Indication: Unique Visualization Planes

Endoscopy is also effective for visualizing and manipulating anterior structures including the posterior iris surface, ciliary bodies, pars plana, ora serrata, and peripheral retina (Fig. 11.5). Using an endoscope, variable visualization planes facilitate anterior vitrectomy, membrane peeling, sclerotomy placement, and diagnostic visualization.

Endoscopic visualization of sutured intraocular lenses (Fig. 11.4), sub-iris and ciliary body abscesses, and anterior PVR precludes aggressive scleral depression, which should be avoided in eyes with recent open globe surgery, unstable intraocular lenses, and filtering blebs [38, 46]. The endoscope also provides in vivo perspectives of structures, without the contortion inherent in techniques that require scleral depression. The multiple direct planes of view offered by endoscopy can provide direct visualization of the traction created by anterior PVR, as opposed to the artificially contorted view of scleral depression observed through the surgical microscope. However, the endoscope does offer a relatively modest field of view and a lack of stereopsis,

limitations not presented by a conventional coaxial operating microscope [2].

Creating a sclerotomy is most likely to be performed atraumatically while under direct visualization. In aphakic eyes where the endoscope can be inserted through a limbal incision, sclerotomies can be created under transpupillary visualization [34] (Fig. 11.9). Complications during the placement of sclerotomies may include ciliary and choroidal hemorrhage or anterior displacement of the vitreous base and retina. Meanwhile, imprecise sclerotomies may result in subciliary, suprachoroidal, or subretinal placement of the infusion line [6]. The intraocular endoscopic view of sclerotomies can prevent such complications.

The maneuvers unique to endoscopy also extend a surgeon's tissue removal capabilities. For instance, even in phakic eyes, the endoscope's flexibility allows for vitreous removal from sclerotomy sites and from the posterior capsule. The view of subretinal space made possible by the

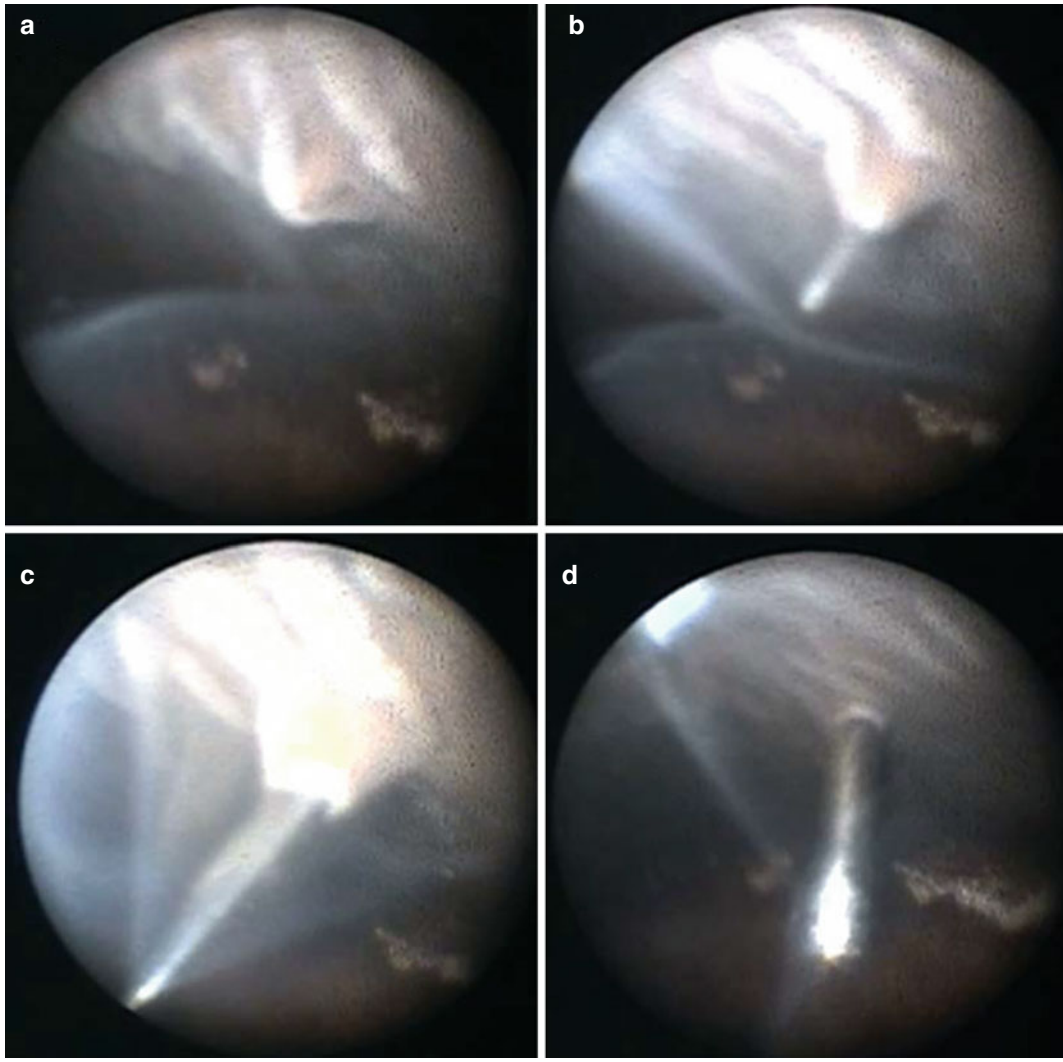

Fig. 11.9 Patient with severe anterior segment disfiguration. Endoscopic view. (**a**) 25-gauge sclerotomy was attempted to be placed 3 mm from limbus in this pseudophakic patient. Note that the blade was going to penetrate through the ciliary processes. (**b**) Blade was retroplaced at 4 mm from limbus, at the anterior pars plana. (**c**) 25-gauge cannula introduction. (**d**) Cannula placed without additional trauma to anterior structures

endoscope allows for the performance of tasks, such as removing migrated subretinal perfluorocarbons or silicon oil, that are challenging in traditional vitrectomy. Similarly, the endoscope's maneuverability allows subretinal bands to be visualized and approached. Maneuvers only possible with an endoscope are of use when preventing retinal slippage during fluid/air exchanges [7].

Intraocular lens (IOL) sulcus fixation is also another valuable indication for endoscopy [38]. It allows precise placement of IOLs on the ciliary sulcus, avoiding trauma to the ciliary processes and posterior surface of the iris. Appropriate passage of sutures, or placement of forceps or small-gauge cannulas in the sulcus for the newer IOL fixation techniques, is directly visualized (Fig. 11.10). It can also be used as a diagnostic and therapeutic aid in eyes with previous complicated cataract surgery with chronic cystoid macular edema and potentially malpositioned IOL. It provides more reliable information about the IOL haptic position than the current ultrasound biomicroscopy (UBM) images.

Finally, the endoscope is a powerful tool in diagnosing cases of severe ocular trauma (Fig. 11.8). When unclear visualization impedes a proper assessment of the viability of the optic nerve and retina, the endoscope's variable perspective may facilitate the diagnosis and aid in any necessary intervention. In some cases, the endoscopic view could reveal that surgery is futile, thus avoiding any further unnecessary iatrogenic trauma.

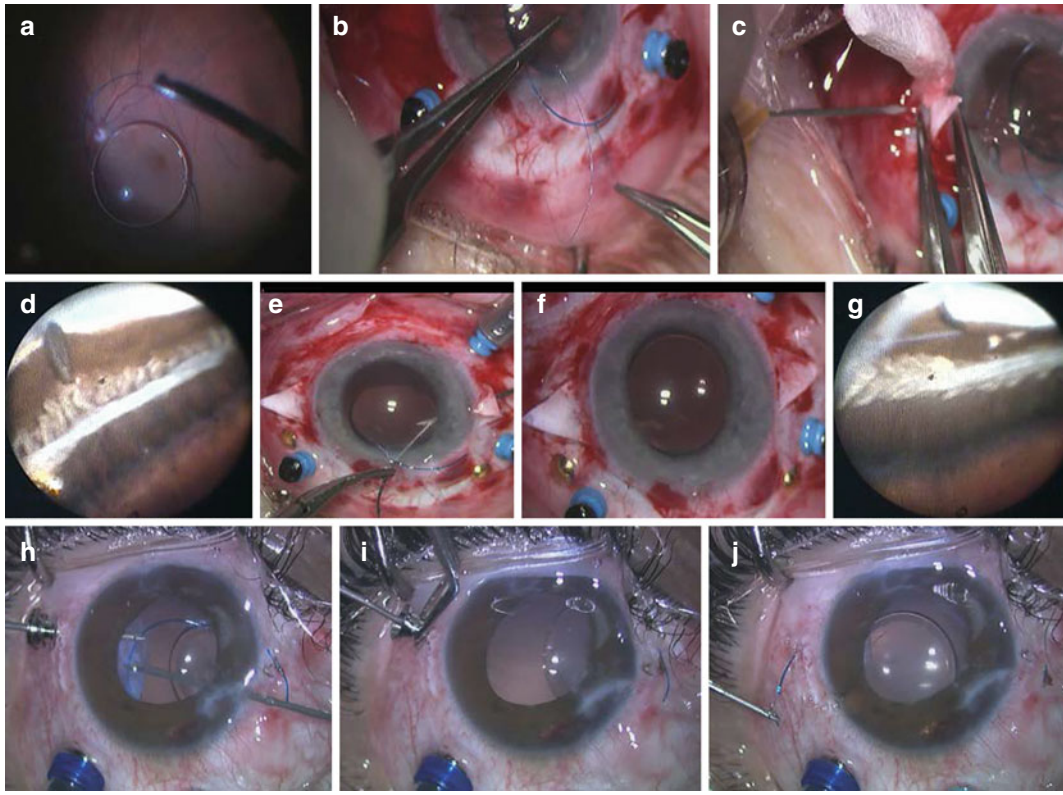

Fig. 11.10 Intraocular lens (IOL) fixation using endoscopy. (**a**) Luxated IOL. (**b**) Suturing the IOL haptic. 26-gauge needle placement in the sulcus (**c**) guided by endoscopy (**d**). (**e**) Passing the 10.0 prolene needle inside the 26-gauge needle for proper suturing in the sulcus. (**f**) Centered IOL after scleral fixation. (**g**) Endoscopic view of IOL haptic sutured in the sulcus. (**h**–**j**) Newer sutureless transconjunctival scleral fixation technique using 27-gauge cannulas placed in the sulcus

11.4.3 Retinal Detachment

11.4.3.1 Primary Retinal Detachment

Vitreoretinal endoscopy can be used for different purposes during primary retinal detachment (RD) repair:

Subretinal Fluid Drainage

Hattori et al. [23] described a drainage technique using endoscopy to decrease the amount of residual subretinal fluid while avoiding posterior retinotomy and liquid perfluorocarbon (PFC) usage. With endoscopy, the patient's head can be substantially tilted towards the same side of the retinal breaks allowing for more complete drainage through the primary retinal break without the need for using long silicone soft-tip cannulas in the subretinal space (e.g., Flynn cannula). This technique can also be useful to decrease slippage during fluid-air exchange in giant retinal tear cases.

Fluid-Air Exchange

Often during fluid-air in the presence of intraocular lens (IOL) and posterior capsulotomy, IOL fogging or condensation decreases substantially our view of the retina. Many techniques have been attempted to manage this bothersome obstacle like using humidified air [22], increasing the anterior chamber temperature [39], decreasing the temperature of the infused air, dispersive viscoelastic coating of the back surface of the IOL, aiming the infusion line towards the IOL, or simply trying to tilt the eye to allow visualization through the edges of the posterior capsulotomy. But sometimes nothing seems to work well. Sonoda et al. [49] have described a technique of using the endoscopy probe for direct visualization of subretinal fluid drainage during fluid-air exchange. It can also be used for a more complete PFC removal. The endoscopic view under air is adequate and it bypasses the fogged IOL. It is a valid alternative to keep in mind in this potentially difficult situation.

Finding the Retinal Breaks

The rate of overall undetected preoperative retinal breaks is around 2–7 % [3]. With the current high-technology microscopes and wide-field viewing systems, many of these breaks can be found during pars plana vitrectomy (PPV). Although previous series have shown comparable success rates with either circumferential scleral buckling alone or in combination with PPV for these cases of unseen retinal breaks [45, 53], many surgeons around the world are becoming more and more accustomed to manage primary RD with PPV alone. A recent report by Jackson et al. on 3,403 eyes operated for retinal detachment between 2002 and 2010 showed that almost 80 % had PPV alone as their primary procedure [27]. Using PFC or even injecting subretinal dye may help finding small peripheral breaks. Kita et al. [29] reported a series of 20 cases of typical primary pseudophakic/aphakic RDs using endoscopy-guided PPV to detect and treat tiny peripheral breaks without the need for PFC, dyes, scleral depression, or anterior segment manipulations such as posterior capsulectomy, pupil stretch, or IOL removal. Using only endoscopy and no other adjuvant, they were able to find and treat the breaks in 95 % of the cases in their series (Fig. 11.11).

11.4.3.2 Complex Retinal Detachment

Anterior Proliferative Vitreoretinopathy

Several cases of rhegmatogenous retinal detachment may present with anterior proliferative vitreoretinopathy (PVR) [5]. Cellular proliferation and contraction at the vitreous base may contribute to multiple retinal redetachments and traction on the ciliary body [13]. Anterior PVR is more common in post-trauma, younger patients, uveitis history, and long-lasting RDs. In many of these cases, corneal transparency, small pupil, posterior synechiae, and fibrotic anterior/posterior capsule may decrease visibility and further increase the difficulty of such surgeries. Vitreoretinal endoscopy in this setup is very instrumental because it allows proper visualization of the anterior structures behind the iris and facilitates the removal of some of the fibrotic tissues in this area [16] (Fig. 11.12).

The one important limitation in our instrumentation is that all commercially available vitreoretinal forceps, scissors, picks, and vitrectors have straight shaft. To reach the anterior vitreous

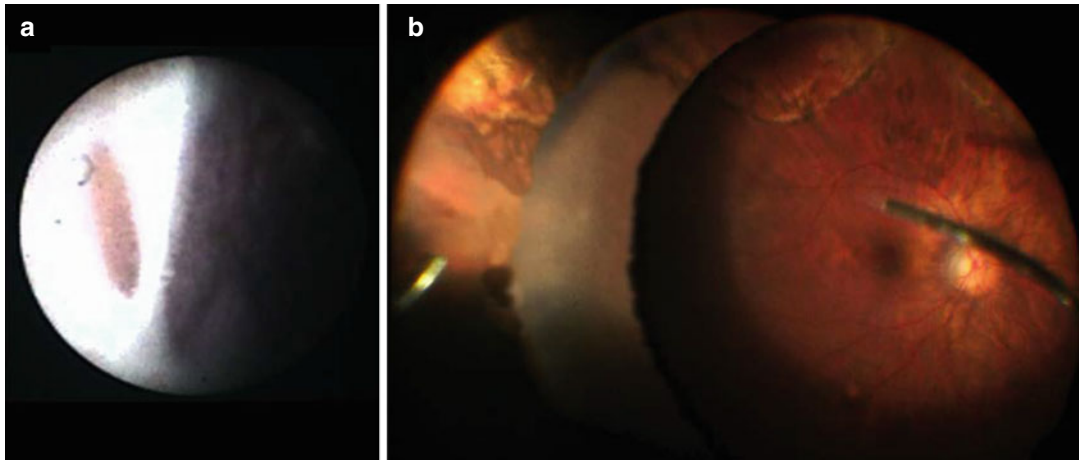

Fig. 11.11 Using endoscopy to find retinal breaks. Tiny retinal hole shown by endoscopy (**a**) responsible for a retinal redetachment not seen during previous surgery using wide-angle viewing system and perfluorocarbon liquid (**b**)

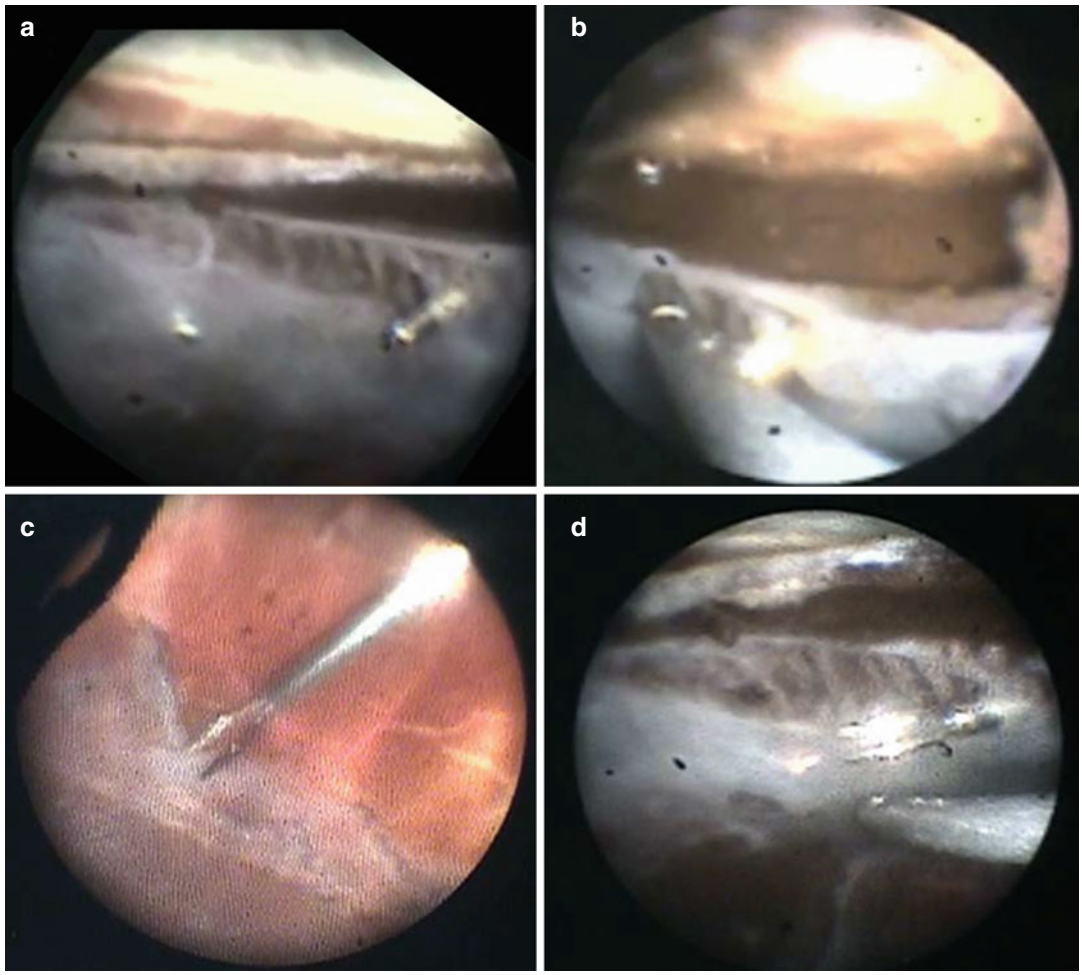

Fig. 11.12 Endoscopy and anterior PVR. (**a**) Anterior PVR covering the entire ciliary body in this aphakic eye. Note that the 25-gauge cannula on the left is under the fibrotic sheath. (**b**) Anterior PVR dissection using the 25-gauge vitrector probe. (**c**) Anterior PVR peeling with 25-gauge end-grasping disposable forceps. (**d**) Anterior PVR bimanual dissection

base with them is rather cumbersome. Using disposable small-gauge instruments, it allows the surgeon to curve the straight shaft of the forceps or vitrector probes, up to a limit, to try to overcome the anatomical barrier of reaching this area (Fig. 11.13).

Another limitation is the fact that the surgeon needs to hold the endoscope probe in one hand so only one hand is free for dissection. We have tried to have the assistant holding the endoscope to allow for bimanual peeling of anterior PVR membranes but this technique is rather demanding and hard to reproduce safely (Fig. 11.12).

A vitreoretinal surgeon with proper endoscopy training will find it very useful in most cases of retinal redetachment with or without PVR. Sometimes, during examination and even while using wide-field viewing system under the surgical microscope, specialists cannot find a reason for the redetachment. The most common example is after silicone oil removal. When using the endoscope, one can detect tiny peripheral retinal breaks (Fig. 11.11) or anterior retinal contraction causing the redetachment (Fig. 11.12). With the advancement of having small-gauge endoscopy probes, the authors recommend to use it at the end of every silicone oil removal case. Besides a meticulous intraoperative exam, often multiple silicone oil droplets are found entrapped on the anterior vitreous base that can be removed under endoscopic view (Fig. 11.14).

Some cases of retinal redetachment after 20-gauge vitrectomy are due to retinal incarceration at the sclerotomy sites. This situation can clearly be identified and managed under endoscopic view without the need for retinotomy/retinectomy (Fig. 11.15).

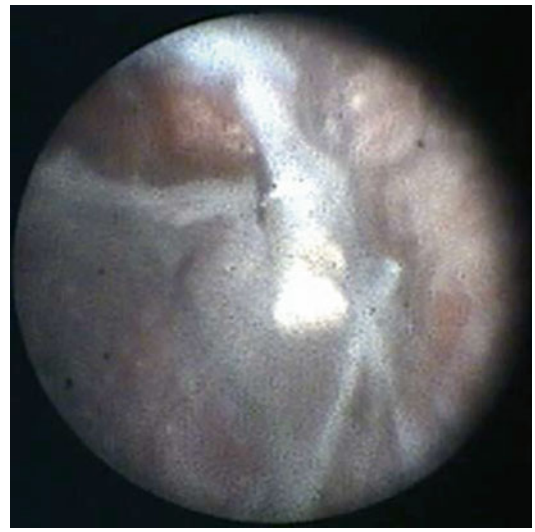

Fig. 11.14 Entrapped residual silicone oil droplet being removed under endoscopic view

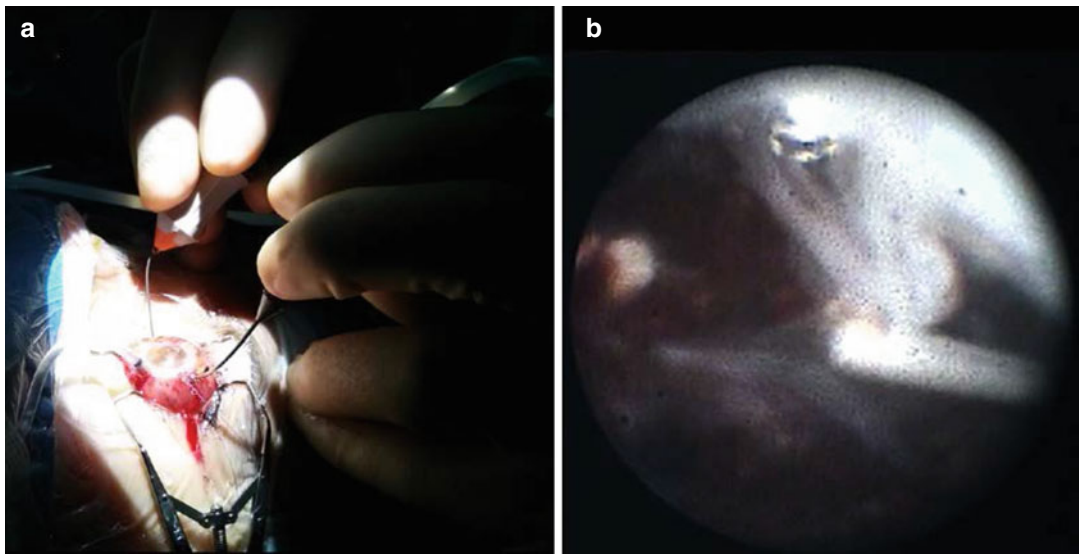

Fig. 11.13 Bent 23-gauge vitrector (**a**) for peripheral proliferative vitreoretinopathy shaving under endoscopy (**b**)

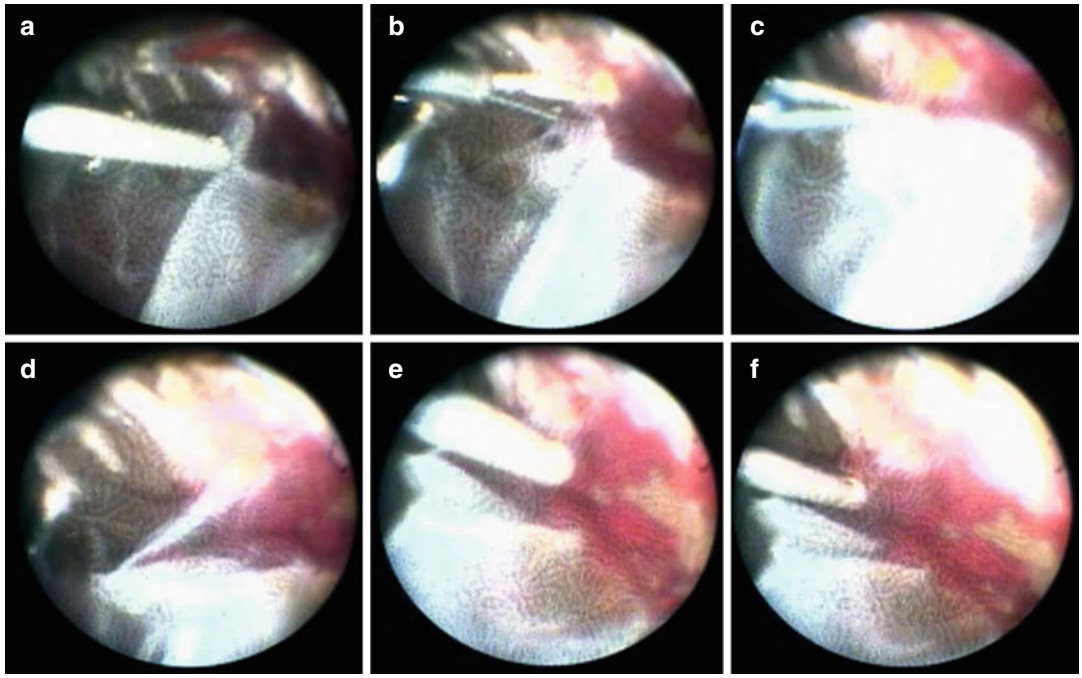

Fig. 11.15 Retinal incarceration after redetachment post-20-gauge vitrectomy under endoscopic view. (**a**) Retina incarcerated at a previous 20-gauge sclerotomy site. (**b**–**d**) Peeling of the incarcerated retina and vitreous. (**e**–**f**) Vitreous shaving with complete cleaning of the sclerotomy site without the need of retinotomy/retinectomy

Retinectomies

Many technological advances have taken place since the introduction of relaxing retinotomy by Machemer [32] followed by large retinotomy and retinectomy by Haut et al. [24]. The introduction of PFC, microincision vitrectomy systems (MIVS) with more rigid instrumentations, valved cannulas, and optimized fluidics control vitrectomy machines has improved the intraocular fluid movement that allows a more precise retinotomy/retinectomy and decreased intraoperative bleeding [26, 47, 50].

Success rate in the eyes with PVR undergoing retinotomy/retinectomy has been shown to be higher with silicone oil tamponade when compared to C_3F_8 and SF_6 gases [55]. Primary and final anatomical success when using retinotomies/retinectomies and silicone oil tamponade to treat advanced PVR ranges from 45–80 % to 68–98 %, respectively. Visual acuity improvement is obtained in about 60 % of patients with most achieving ambulatory vision. Postoperative complications include corneal decompensation with band keratopathy, retinal redetachment, hypotony, glaucoma, optic disc pallor, and phthisis bulbi [12, 19, 21, 51, 55]. Large-gauge endoscopy has also been shown to be useful in these complex cases [16, 44] (http://www.youtube.com/watch?v=jLxEAyMFMi8).

But despite all these advancements, the literature is rather scarce on the management of PVR using retinectomy with MIVS [26]. With the addition of the small-gauge endoscopic probe (OME 230 SMA EA, Endo Optiks, Little Silver, NJ, USA), the authors now recommend performing routinely MIVS with small-gauge endoscopy for any PVR case requiring relaxing retinotomy/retinectomy (Fig. 11.16). This technique allows for a more precise cut of the retina due to the smaller port diameter and its proximity to the tip of the vitrectomy probe. The intraocular environment is better controlled with small-gauge valved cannulas allowing very little fluid leakage. The improved fluidics decreases retinal movement during retinotomy/retinectomy and bleeding. The small-gauge endoscope allows for better visualization of the anterior retinotomy flap that can be

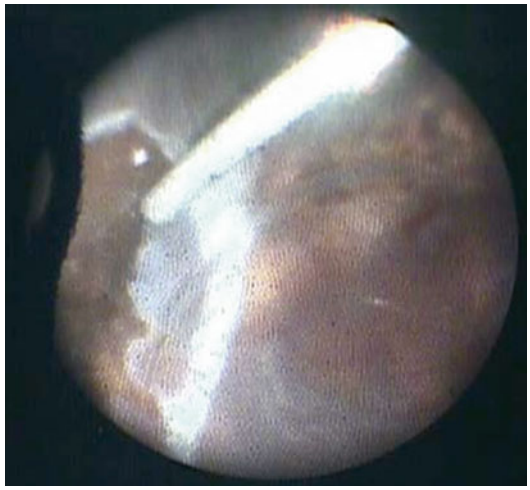

Fig. 11.16 Retinectomy under small-gauge endoscopic view using a 23-gauge vitrectomy probe and perfluorocarbon liquid to stabilize the retina

thoroughly excised with the small-gauge vitrector. Another very interesting usage of endoscopy during this maneuver is when inadvertent bleeding occurs. In this situation, the surgeon can raise the level of PFC. The blood does not mix with PFC, so when you put the endoscope inside the PFC bubble, the view remains clear despite the blood on the anterior surface of the PFC. The retinotomy or PVR peeling can proceed under endoscopy with good visibility, which wouldn't be possible using only the surgical microscope with wide-angle viewing system (Fig. 11.17).

The surgeon can often find under endoscopic view in retinal redetachment cases a contraction of previous incomplete retinectomy causing traction on the retina or over the ciliary body. Again, in many situations, this would not be possible using the surgical microscope with wide-angle viewing system (Fig. 11.18).

An endoscopic surgical technique that is useful in these complicated situations is to enter very anteriorly with a small-gauge vitrectomy probe between the fibrotic tissue and retinal pigment epithelium (Thorpe) or the ciliary body, turn the port towards the retina or the fibrotic tissue, and remove it from the outside-in. This decreases the trauma to the underneath RPE and choroid (Fig. 11.19).

At the end of the retinectomy and fibrotic tissue dissection under PFC, air-fluid exchange is performed and silicone oil injection completed. Endoscopy also helps to maintain good visibility under air and silicone oil (Fig. 11.20). When using 23 gauge, we prefer to suture all sclerotomies transconjunctivally to avoid subconjunctival silicone oil leakage. More recently, the authors are avoiding performing endolaser at the retinectomy edges. We believe this further increases the risk of PVR and contraction of the retinectomy. We recommend waiting 3–4 months post-op to perform light laser around the retinectomy prior to silicone oil removal.

11.4.4 Tractional Ciliary Body Detachment

Many believe that few treatment options are capable of saving a hypotonous eye. For eyes that are hypotonous due to an epiciliary body membrane, however, the endoscope makes possible epiciliary membrane peeling via its unique visualization of the anterior structures. This technique is very difficult using the view offered by conventional microscopes, but the perspective offered by ophthalmic endoscopy ameliorates these challenges faced by traditional methods of epiciliary body membrane peeling. A video of retinal detachment repair with epi- and subciliary membrane peeling in a hypotonous eye is available at: http://www.youtube.com/watch?v=bZEMuM6vpK4. The relatively new techniques made available by novel endoscopic technology are currently methods rich with topics for clinical research regarding their efficacy and clinical outcomes.

Tractional ciliary body detachment usually develops in the eyes with chronic uveitis, anterior PVR, post-extensive retinectomy with remaining anterior flap, and post-penetrating/perforating ocular trauma. The most common presentation is after large relaxing retinotomies/retinectomies. In this setting, chronic hypotony rate is around 7 % [12]. As mentioned above, anterior PVR dissection and extensive anterior retinectomy flap removal under endoscopy are crucial in trying to decrease its incidence.

We consider early endoscopic intervention in the eyes with unexplained postoperative hypotony in the presence of attached retina. In these cases, UBM can aid in confirming the diagnosis

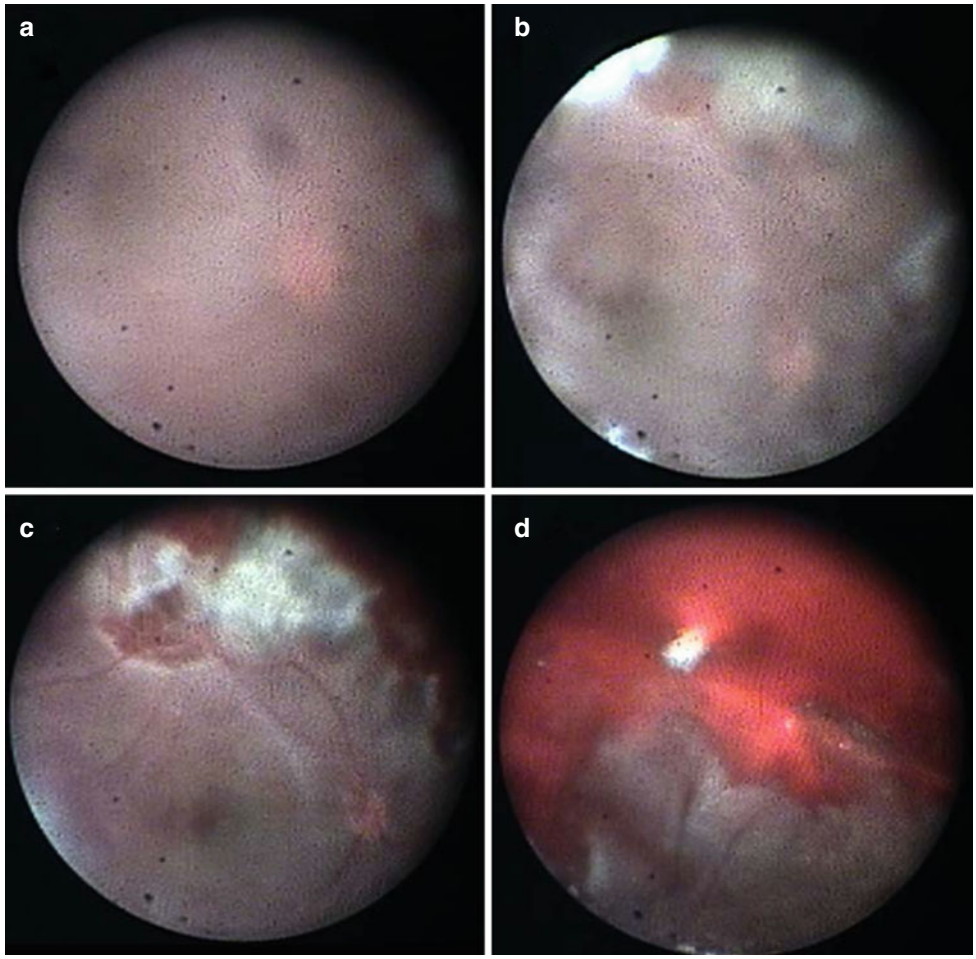

Fig. 11.17 Retinectomy under endoscopic view using perfluorocarbon liquid (PFC). (**a**) Hazy view due to bleeding from retinectomy edges. (**b**) PFC injection. (**c**) Clear view with the endoscope inside the PFC bubble allowing to proceed with the retinectomy. (**d**) Hemorrhage confined to the retinal periphery

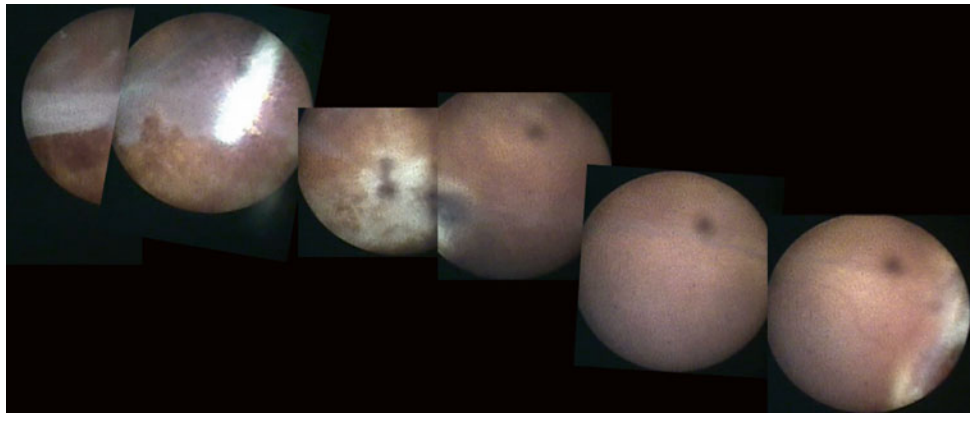

Fig. 11.18 Retinal redetachment case post-silicone oil removal. Note on the *left* that the remaining anterior retinectomy flap (being excised by the vitrector) had contracted and caused the retina (on the *right*) to redetach. The cause of the redetachment had not been previously identified on the clinical examination or under microscopic wide-angle viewing

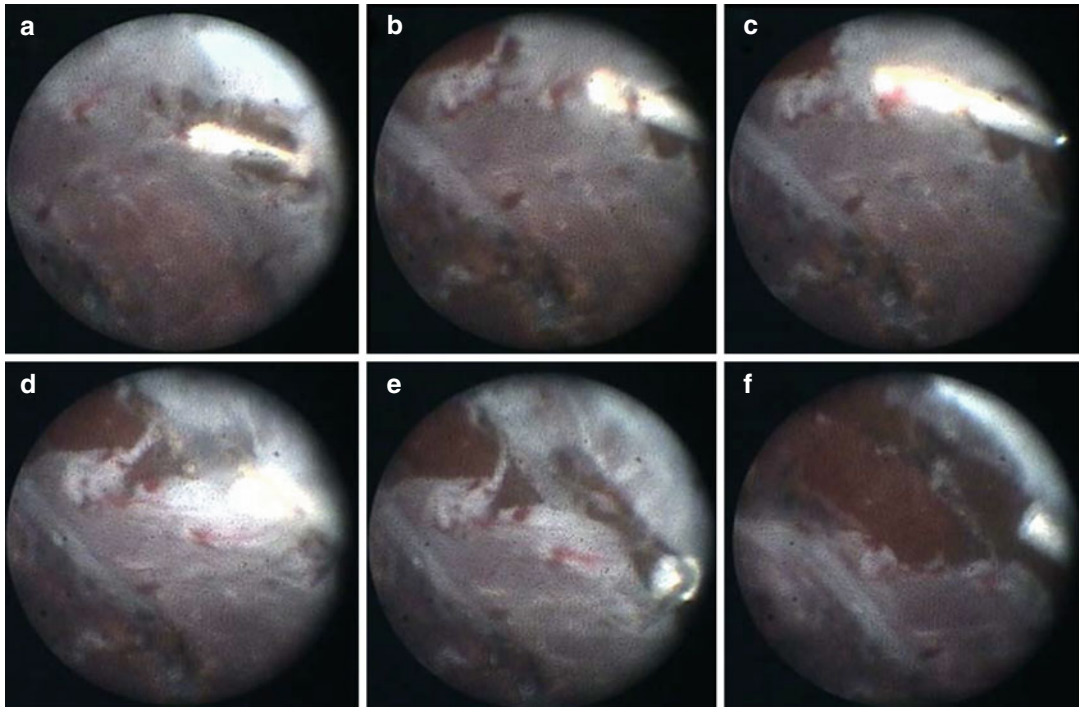

Fig. 11.19 Anterior retinectomy under endoscopic view using the outside-in technique. (**a**–**c**) Advancing the vitrector anteriorly, between the fibrotic retina and the retinal pigment epithelium (Thorpe), with the port facing the neuro-retina and the cutter off. (**d**–**f**) Retracting the vitrector while cutting the retina from the outer to the inner retina. Note the intact RPE and choroid at the retinectomy area

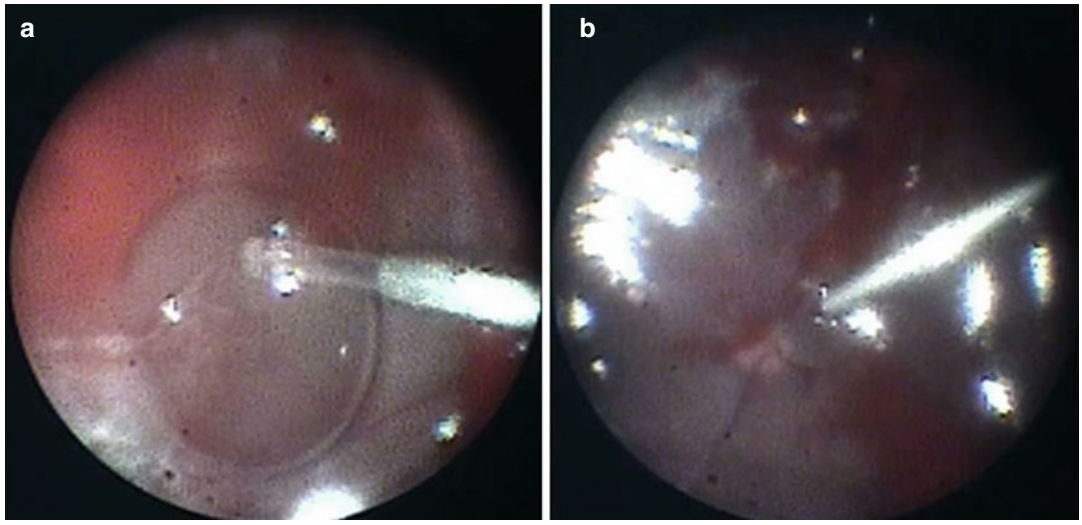

Fig. 11.20 (**a**) Endoscopic view under silicone oil. Clear image allows for removal of residual perfluorocarbon liquid bubble. (**b**) Endoscopic view during air-fluid exchange

[35, 42] (Fig. 11.21). With this early approach, hypotony can be reverted even in the presence of extensive retinectomy. But if management is delayed, thick fibrotic tissue may install with resulting inoperable severe ciliary body traction and atrophic ciliary processes (Fig. 11.22). Most of these eyes without timely management will eventually become phthisical.

11.4.5 Posterior Segment Trauma

11.4.5.1 Ocular Penetrating/ Perforating Wounds

Penetrating and perforating ocular injuries can often present as a great challenge for the vitreoretinal surgeon. It is frequently associated with media opacities and tractional retinal detachment (Fig. 11.23). After the primary globe repair, retinal incarceration and tractional ciliary body detachment may occur. The techniques to approach these situations have been described above. In case of post-primary globe repair hypotony, early reintervention should be considered to avoid maturation of PVR membranes and irreversible damage to the ciliary body (as mentioned above).

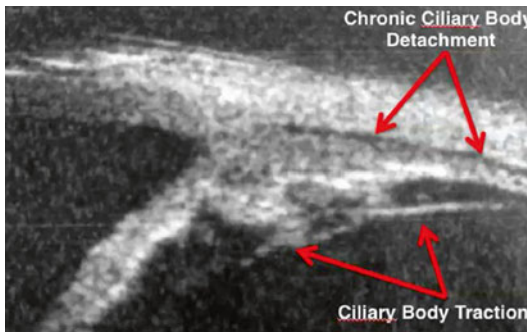

Fig. 11.21 Ultrasound biomicroscopy showing tractional ciliary body detachment

11.4.5.2 Intraocular Foreign Bodies (IOFBs)

Intraocular foreign bodies can be lodged in any ocular structure. In cases of corneal lacerations, corneal bloodstaining, or post-traumatic endophthalmitis, the view to the vitreous and retina may be suboptimal for performing conventional microscope-assisted vitrectomy. In these instances, rather than performing emergency corneal grafting surgery, an endoscope-assisted pars plana vitrectomy may be performed for the removal of the IOFB and treatment of retinal tears caused by it. Without proper visualization, removing IOFBs can create giant retinal tears that result in poor postoperative prognosis [48].

Since some retained IOFBs can be more often associated with post-traumatic endophthalmitis,

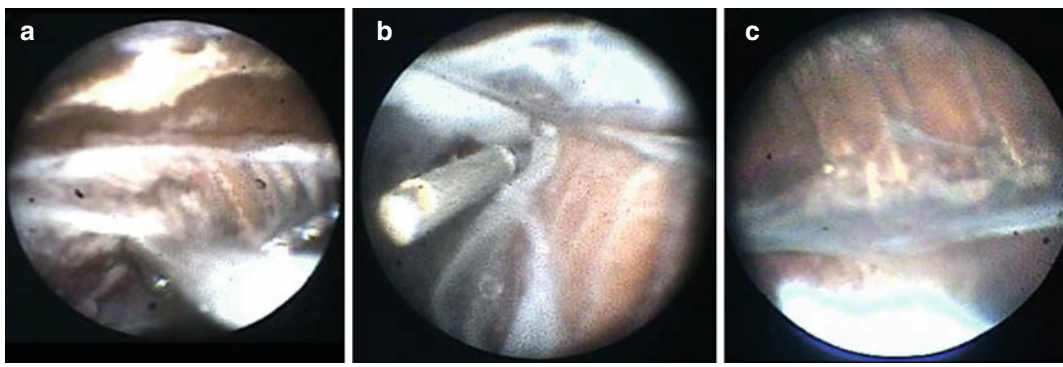

Fig. 11.22 Endoscopic view in tractional ciliary body detachment. (**a**) Tractional ciliary body detachment with chronic hypotony in an eye with attached retina and previous retinectomy. Note the thick fibrotic tissue over the whitish atrophic ciliary processes. (**b**) Chronic hypotony with tractional ciliary body and retinal detachment in a young patient with severe intermediate uveitis. (**c**) Early intervention in an eye that had undergone retinectomy with postoperative hypotony. Note that the fibrotic tissue is thinner and the ciliary body has normal color appearance. After endoscopic anterior membrane peeling, the hypotony was reverted

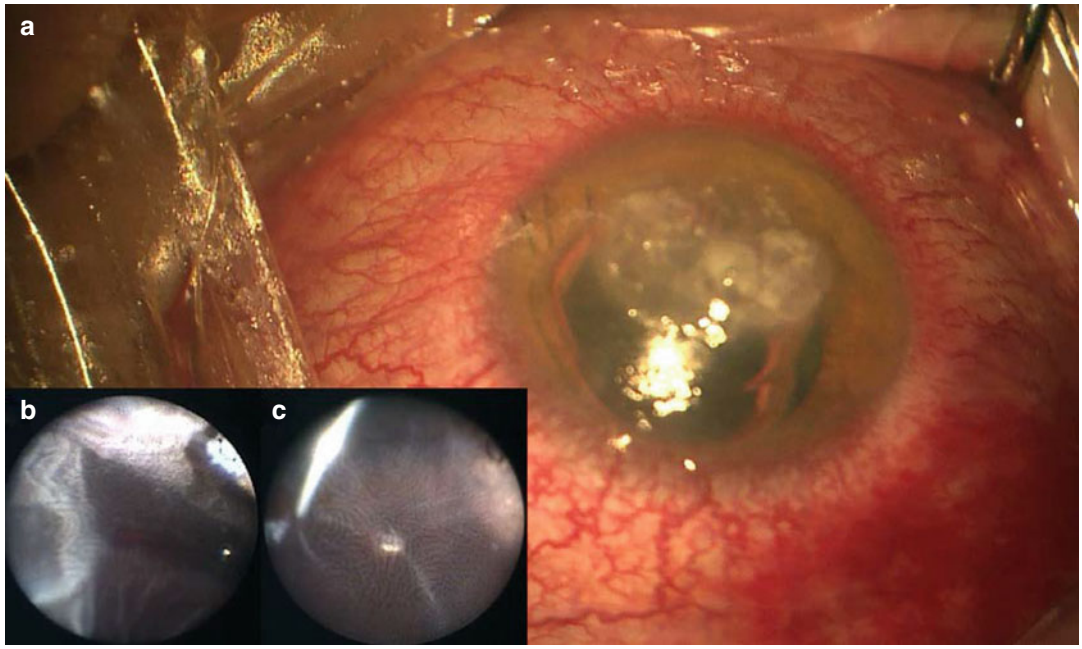

Fig. 11.23 Severe ocular perforating injury. (**a**) Large corneal laceration repaired primarily with sutures and cyanoacrylate glue. Second surgery was performed under vitreoretinal endoscopic view show anterior retinal incarceration at the entry wound (**b**) as well as a smaller retinal incarceration at the exit wound (**c**)

early intervention may be recommended in such cases [1, 15]. Delayed excision increases the risk of IOFB encapsulation and further complicates its removal.

While the microscopic view is typically sufficient to safely remove a foreign body, endoscopic visualization may serve as an alternative option for IOFB removal [4]. A study by Sabti and Raizada described their experience using endoscopy to treat 11 open globe injuries with retained IOFBs. All eyes had retinal tears and vitreous hemorrhage; six eyes required lensectomy. Out of the 11 eyes in the study, ten eyes experienced improved vision following endoscopic vitrectomy [43].

An IOFB lodged in the ciliary sulcus, for instance, can be often missed in clinical examination and only found after imaging such as CT scan. Endoscopic removal of the buried IOFB is the optimal procedure in this setting where the endoscope is inserted into the anterior chamber through a limbal incision and IOFB forceps are used guided into the sulcus by viewing the image from the endoscope (Fig. 11.24).

11.4.6 Understanding the Suprachoroidal Space

Over the years, the vitreoretinal surgeon has learned to avoid and "fear" the choroid and the suprachoroidal space in a similar manner that the anterior segment surgeon has done with the vitreous. But newer imaging technologies using swept-source optical coherence tomography [17, 31] and surgical technologies placing cannulas and micro catheters in the suprachoroidal space are allowing vitreoretinal specialists to better understand the choroid and the choroido-scleral interface and to potentially use this knowledge to improve the management of various complicated vitreoretinal diseases.

Suprachoroidal drug delivery has been advocated to treat recalcitrant or intractable macular diseases [37, 41, 52]. Surgical techniques placing transconjunctival cannulas in the suprachoroidal space to drain serous and hemorrhagic choroidal detachments have greatly simplified the approach of this surgical complication [40]. More recently, temporary

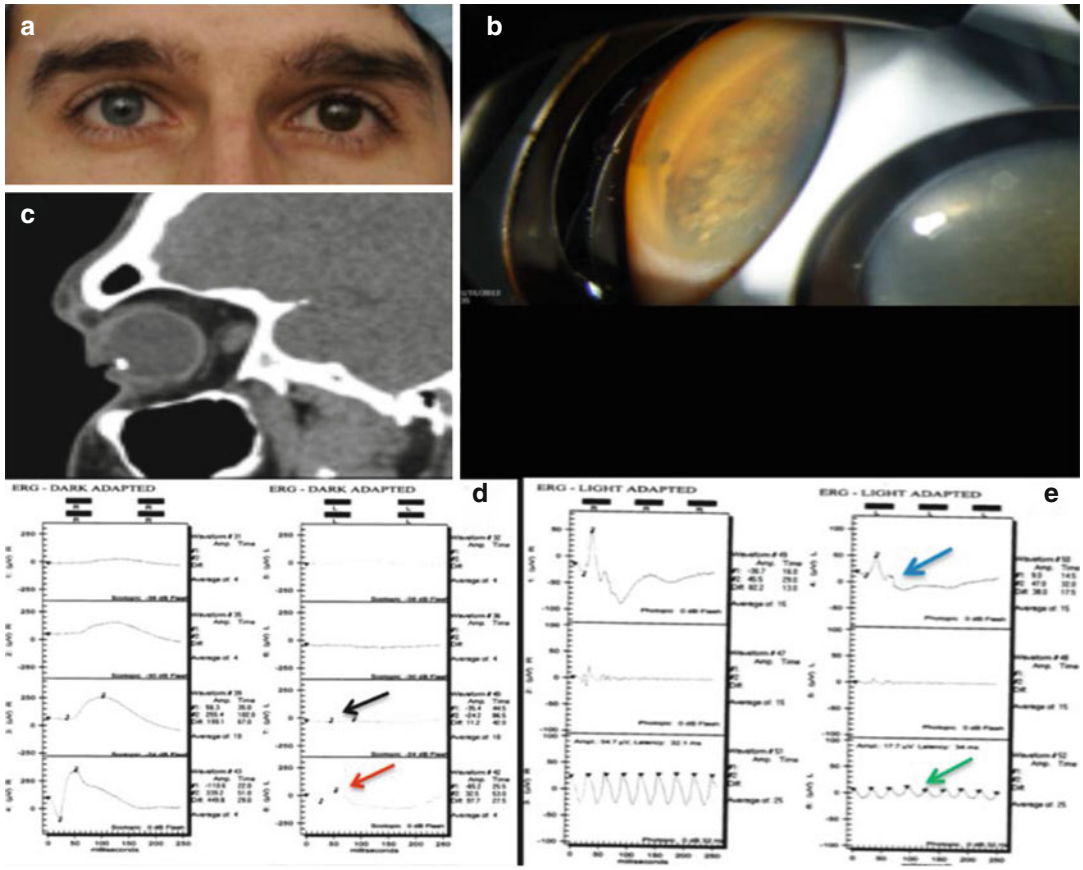

Fig. 11.24 29-year-old man presenting with siderosis bulbi in the *left* eye 1 year after being hit in the eye by metal beam and having had cataract surgery at the time of the injury where a ciliary sulcus intraocular foreign body (IOFB) was missed. (**a**) Iris heterochromia (*left* eye). (**b**) Gonioscopy did not reveal an IOFB. (**c**) The IOFB seen on CT scan. (**d**) Full-field dark-adapted electroretinogram shows rod isolated b wave 5 % of normal (*black arrow*) and the maximal stimulation b wave (combined rod and cone response) to be 30 % of normal in the *left* eye (*red arrow*). (**e**) Full-field light-adapted electroretinogram shows photopic flash b wave (*blue arrow*) and 30 Hz flicker b wave (*green arrow*) to 35 % of normal in the *left* eye

suprachoroidal buckling with viscoelastic injection into the suprachoroidal space has shown interesting results to treat inferior RDs and myopic macular holes [14].

To better understand where exactly are we injecting or placing these substances or instruments, the authors have used small-gauge endoscopy to visualize this space and perhaps to aid demystify this surgical frontier.

Figure 11.25 illustrates the clear viscoelastic separation of the choroid from the sclera creating a suprachoroidal buckling effect to treat RD. Getting used to this image of clear choroido-scleral separation may permit vitreoretinal surgeons to securely place cannulas and micro catheters into the suprachoroidal space with measured concerns about damaging choroidal vessels.

11.5 Pediatric Complex Vitreoretinal Cases Indications

Pediatric retinal detachments due to retinopathy of prematurity [21] or familial exudative vitreoretinopathy (FEVR) pose unique challenges to the vitreoretinal surgeon [11]. Unlike typical adult RD, pediatric RD do not usually arise from

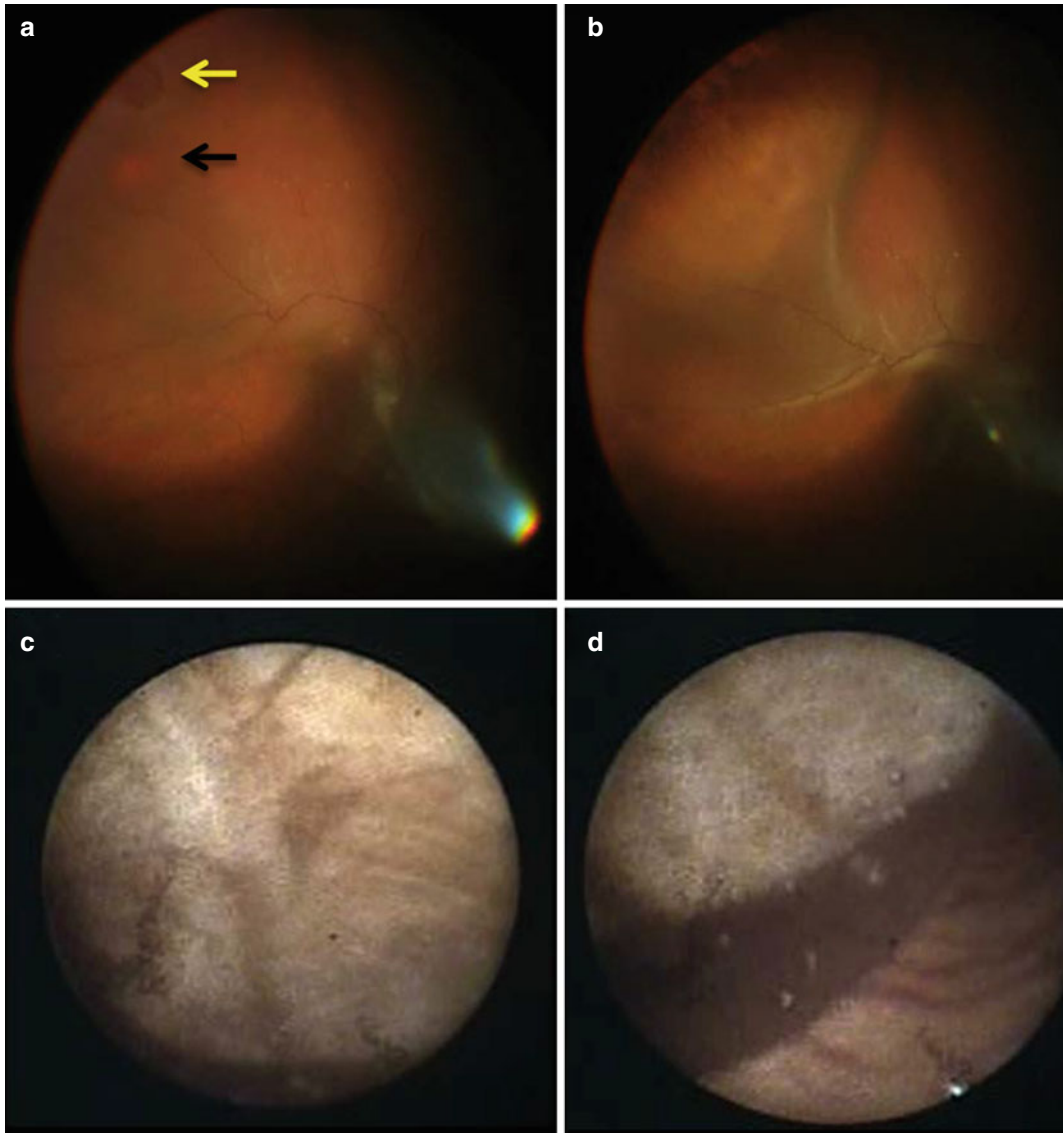

Fig. 11.25 Endoscopic view of the suprachoroidal space. (**a**) Inferior retinal detachment with a single retinal break (*yellow arrow*). Note the flashing red light of the micro catheter placed in the suprachoroidal space just posterior to the break (*black arrow*). (**b**) Buckling effect with choroidal indentation closing the retinal break. (**c**) Endoscopic view of the inner scleral surface. (**d**) Endoscopic view of the viscoelastic clearly separating the choroid on the *right* from the sclera on the *left*. Note the well-delineated choroidal vessels

a posterior vitreous detachment (PVD) leading to a horseshoe tear. Instead, they are often tractional in nature with the neovascular pathology occurring in the far periphery, sometimes involving anterior structures like the ciliary body and lens capsule. Visualization can often be challenging due to the smaller pupil size of infants and the recessed nature of the associated membranes [30]. In addition, the neovascular membranes can be tightly adherent to the retina, and, unlike adults with tractional diabetic detachments, the posterior hyaloid can be extremely difficult to detach [58].

Conventional viewing systems have two disadvantages when approaching these cases. The first is that visualization of the peripheral surgical

field can be quite limited. The location of the membranes can often extend to the ciliary processes and posterior lens capsule, which can be outside the view of traditional microscope wide-angle viewing systems. In cases with a tractional membrane coming up to the lens, the top-down perspective may not distinguish the transition between the fibrosis membrane and the retina, thus making it difficult to know where to safely cut and trim with the vitrector. In cases of ROP, the diameter of the external viewing lens (either contact or indirect) can be large relative to the infant eye and may limit the angle of entry of the instruments that must come in 1 mm posterior to the limbus. This can be constraining from the standpoint of rotating the globe as well as how peripheral the surgeon can access especially when performing a three-port vitrectomy. The combination of far peripheral location and suboptimal perspective creates conditions where the surgeon may not be able to adequately visualize the pathology and inadvertently make an iatrogenic hole. Unlike adult RDs, an iatrogenic hole in a pediatric tractional RD can be very difficult to recover from.

The second disadvantage is that the standard light pipe typically illuminates the eye using transmitted light that is bounced off the posterior pole to provide a red reflex with the usable light passing through the vitreous thus making direct visualization of the vitreous membranes difficult. Because a PVD is exceptionally difficult to induce in young children, the surgeon does not have the benefit of a PVD to assist in a complete and thorough vitrectomy [28]. Instead, it is assumed that the hyaloid will remain attached and there will be vitreous left behind. Thus, it is imperative that the surgeon knows exactly what vitreous was cut and what was left behind. Without a direct view of the vitreous, this can be quite challenging. In addition, more subtle but pathologically significant membranes can be missed.

Endoscopic vitrectomy provides a unique approach that directly addresses these two deficiencies in standard microscope wide-angle viewing systems. By placing the viewing perspective inside the eye, the surgeon is able to visualize the surgical space immediately behind the iris and lens where tractional membranes can be attached [8, 36, 38]. In the case of ROP, there are multiple layers that can arise from the stage 3/stage 4 extending in both circumferential as well as anterior-posterior directions. The endoscope allows for excellent visualization of all of these and in particular the anterior membranes. Because the endoscope is approaching the membranes from the side, the surgeon can also more clearly delineate at what point the scar tissue arises from the retina and where it is safe to cut. Likewise, it is easier to know where the membrane stops and the lens capsule begins (Fig. 11.26). This allows for careful membrane dissection that minimizes the risk of creating a retinal hole or cataract. This is in contrast to what an external view would provide looking from the top-down. There are many instances when the noncontact wide-angle viewing system is not able to visualize these structures while the endoscope provides a clear and magnified view. In addition, the internal view also allows the surgeon to avoid any anterior media opacities. Specifically, cases of aggressive ROP have often had extensive laser and may have associated posterior iris synechiae that have bound the pupil into a more constricted state. There can also be residual persistent tunica vasculosa as well as anterior vitreous hemorrhage behind the lens capsule. All of these could dramatically interfere with the view from a standard external viewing system and make careful membrane dissection extremely complicated.

The illumination arrangement of a multifunction endoscope also greatly enhances the ability of the surgeon to identify vitreous pathology that would otherwise be poorly visualized by an external viewing system. Specifically, the side-by-side placement of both the camera and illumination fibers creates a coaxial lighting system that allows the camera to efficiently capture and detect light that is reflected off of the vitreous and associated thin membranes. With a coaxial arrangement, the vitreous appears somewhat opaque, and cortical membranes and neovascular sheets appear white (Fig. 11.27). It is this reflection off the pathology that gives the endoscope a unique advantage in dealing with the complex

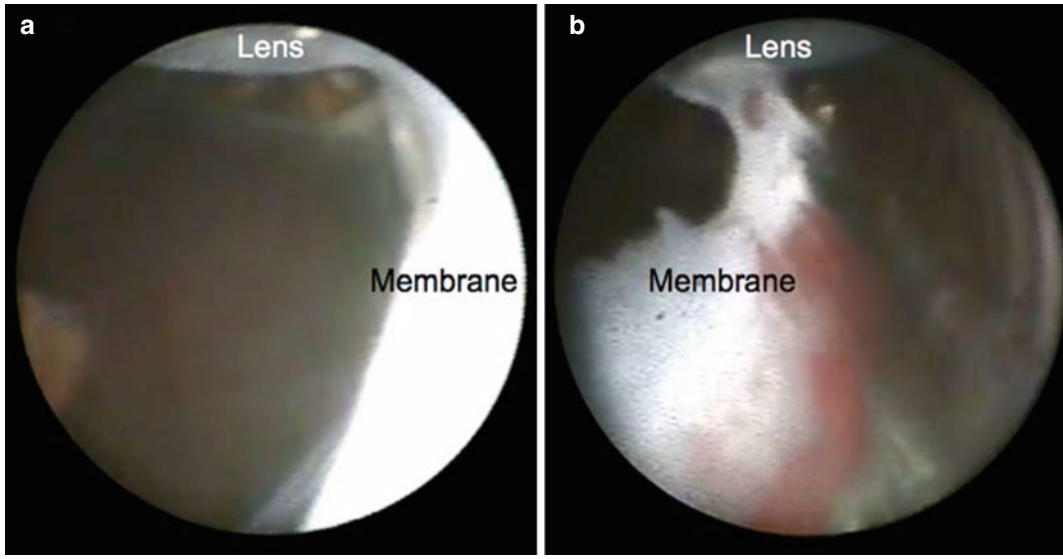

Fig. 11.26 (**a**) The side view provided by the endoscope clearly shows the relationship between the fibrotic membrane and the implantation up to the posterior lens capsule. (**b**) The vitrector was able to safely cut the membrane from the lens without causing any rupture of the lens capsule

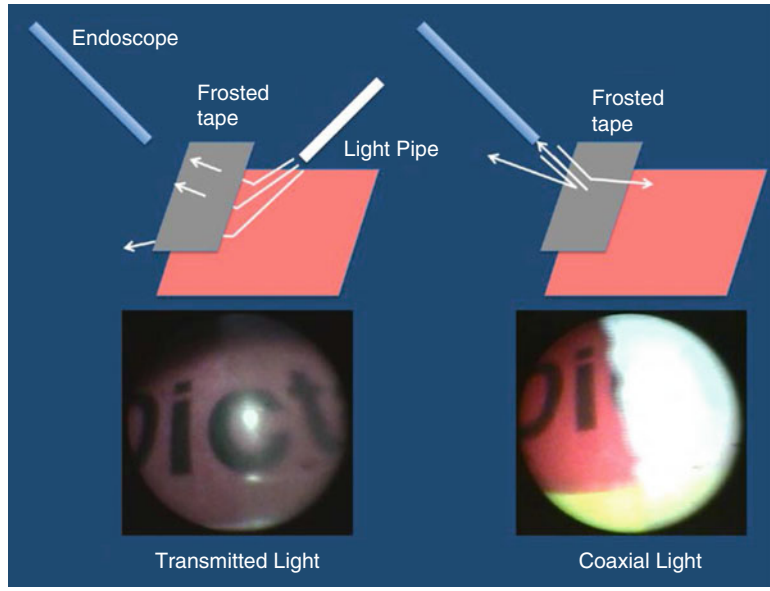

Fig. 11.27 In this simulation of vitreous membranes, a *red* background and frosted cellophane tape were immersed in water, and a viewing endoscope along with separate light pipe was used to illuminate the cellophane tape using transmitted light going through the tape revealing very little of the tape. In contrast, when coaxial lighting was used coming from the endoscope, the cellophane tape became immediately visible as an opaque structure highlighting the increased visualization achieved with the endoscope

arrangement and insertion points found in ROP and FEVR membranes. With external microscope wide-angle viewing systems, however, the light emitted from the endoilluminating probe passes through the vitreous to the external lens with the informative component reflected back into the eye undetected.

A third advantage of the endoscope is the high degree of magnification it can achieve by bringing the lens tip close to the pathology and membranes. A primary dilemma in pediatric retinal surgery is being able to distinguish between vascularized retina and more fibrotic vitreous membranes. The coaxial lighting can illuminate the membranes, but to distinguish them from the retina, it helps to confirm that the membrane is avascular. The magnification provided by the endoscope is directly proportional to the distance of the tip of the probe to the pathology. The closer the probe tip is to the membrane, the more detail it can provide. This high degree of magnification of the endoscope allows the surgeon to see very small details down to individual vascular branches that would be present in the peripheral retina. This resolution makes it relatively easy to determine where the avascular membranes can be cut to release the tension on the retina.

Although there are several advantages to using an endoscopic viewing system, the surgeon must be careful with certain limitations. The first is that as the probe comes closer to a structure, the magnification increases while the field of view decreases. As a result, great care must be used when moving the vitrector or other tissue-manipulating instrument outside the field of view of the endoscope especially when dealing with structures at high magnification. It is better to pull away with the endoscope and increase the field of view than try and move the instrument back into the view of the endoscope. Also, it is possible to become disoriented while in the small pediatric eye with respect to anterior and posterior landmarks, and so it is useful to always have one reference point in view (optic nerve, ora serrata, or iris). These are challenges at the beginning of the learning curve that can be overcome with experience (as addressed above).

The combination of internal perspective, coaxial lighting, and high magnification makes the endoscope a useful imaging system for addressing the complex tractional membranes present in ROP, FEVR, and other complex pediatric retinal detachments. These features of the endoscope allow the surgeon to approach pediatric RDs with a higher degree of confidence by providing a more informative surgical view. This in turn creates an environment where the surgeon is able to more thoroughly remove pathologic membranes while minimizing the risk of creating iatrogenic retinal holes and cataracts.

11.6 Future Directions

The current illumination/endoscope probes available on the market require surgeons to devote one working hand to hold it to image the area of the retina or vitreous of concern. The superiority of bimanual surgery is evident in virtually all surgical specialties, and it is performed in vitreoretinal surgery with the aid of chandeliers. Bimanual surgical techniques are sometimes necessary in highly complex cases of tractional RDs and in some luxated IOL fixation techniques. Some surgeons even use routinely to facilitate its independency from having an assistant and to improve video recordings. Due to the need of developing bimanual endoscopic surgery as well as alleviating the pains of endoscope orientation, a research group based at the University of Michigan, USA, along with Dr. Flavio Rezende, University of Montreal, Canada, devised an endoilluminator technology that "automatically" tracks the surgical instrument during surgery to maintain both the lighting quality and endoscope orientation [60].

This approach employs a closed-loop video feedback system that corrects for the position of the surgical tool, automatically redirecting the light source/endoscope to achieve a focused image. The device employs a shape-memory alloy, SMA, actuated flexible tip, an instrument tracking system, and a holder. The endoilluminator closely resembles a regular light pipe in size and shape, and it is introduced inside the eye

through a 23-gauge cannula, to which it is locked to avoid any unwanted movement (Fig. 11.28). At the distal end, there is a flexible portion, enclosing the optical fiber, which is actuated via three-SMA wire loops that are symmetrically arranged around the flexible end. When current is applied to heat the SMA loops, this flexible portion bends to direct a focused light/camera (Fig. 11.29). Because of the high force-to-weight ratio, fast reaction time, large deformation range, scalability to meet desired gage sizes, ease of manufacture, and low cost, SMA wires prove an effective actuation solution to this endoilluminator. Most importantly, the use of SMA wires allows the entire actuation mechanism to be housed inside the eye.

A video feed from the endoscope is used to determine the location of the tip of the surgical instruments, such as a vitrector and an intraocular forceps (Fig. 11.29), via image processing. Pixels from the RGB (red, green, and blue) color space are mapped to the HSV (hue, saturation, and value) color space, where the tool is identified as being either brighter or darker than the background. After applying several filters, the instrument tip location is confirmed. A feedback control program uses this information to send a corrective command to the SMA actuator, which in turn bends the flexible end of the endoilluminator to provide focused light at the instrument tip (Fig. 11.29).

A holder was also designed to provide mechanical support for the endoilluminator outside the eye. When the endoilluminator is introduced

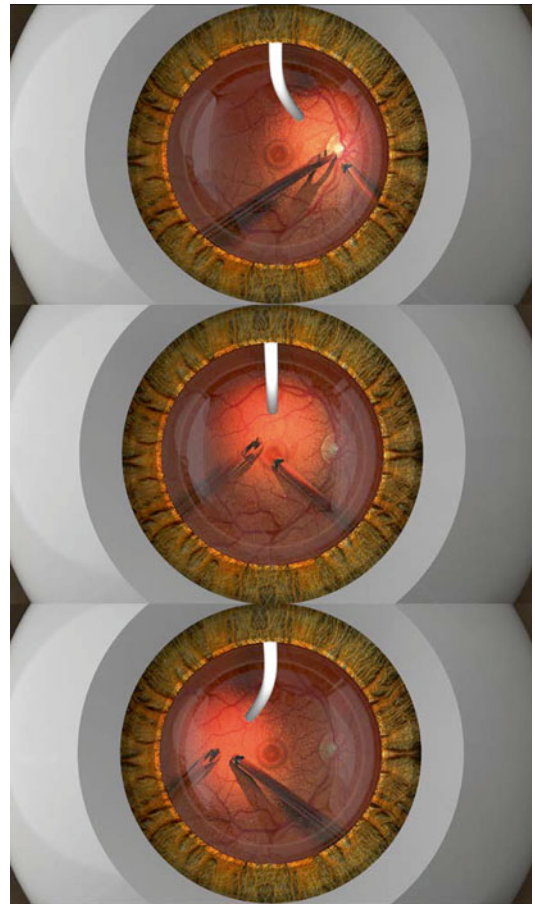

Fig. 11.29 Close-up illustration of the steerable endoilluminator/endoscope with tracking system. Note that as the instruments move from right to left, the light and endoscopic image move automatically, providing constant visibility for bimanual membrane peeling dissection anywhere inside the eye

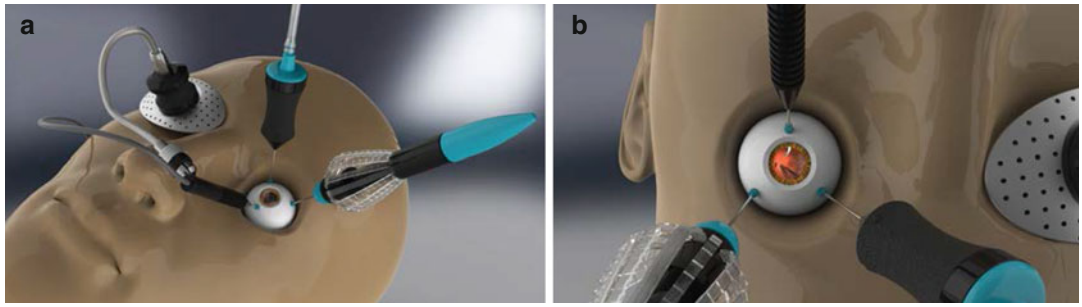

Fig. 11.28 Illustration of the mechanical arm supporting the endoilluminator/endoscope probe, allowing for bimanual endoscopic vitreoretinal surgery

in the eye, the surgeon can prebend the holder such that the endoilluminator is securely positioned in a desired direction. Since the actuation of the flexible end inside the eye is completely automatic, the surgeon can perform bimanual maneuvering in the vitreous cavity without being concerned about the orientation of the image (Figs. 11.28 and 11.29). The holder consists of a magnetic base that mounts on the eye-shield over the nonoperative eye, held in place by a complementary magnet positioned underneath the aforementioned eye-shield. The holder's base subsequently connects to an adjustable interlocking metallic conduit that can be prebent into any desired shape and forms the "neck" of the holder. This neck culminates in a ball-and-socket joint where the endoilluminator is ultimately attached (Fig. 11.28). The adjustable neck allows surgeons to easily set the initial orientation of the endoilluminator. The simplicity of the attachment and anchoring of the holder via the use of magnets minimizes both the setup and cleaning time before and after surgery. The holder is also compact in size; thus, minimal burden is added on an already crowded surgical field. Furthermore, the holder's design contributes to safety during operation. Because the holder is ultimately referenced with respect to the patient's head via the eye-shield over the nonoperative eye, if the patient were to inadvertently move during surgery, the endoilluminator retain their relative position with respect to the globe.

The next challenge will be to develop curved or bendable instrumentation that will allow easier access of vitrector, forceps, and scissors into the far retinal periphery and ciliary body regions. New technology for better image acquisition should also improve the quality of endoscopic tissue visualization that, despite recent advancement, still is much inferior to the newer-generation surgical microscopes.

In summary, this chapter illustrates the ever-growing indications and techniques for vitreoretinal endoscopy to help in the surgical management of complicated vitreoretinal diseases. Upcoming future improvements should attract more adepts to this important surgical adjunct tool.

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Vitreoretinal Considerations in the Setting of the Permanent Keratoprosthesis

12

Michael A. Klufas, Donald J. D'Amico, and Szilárd Kiss

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12.1 Introduction

Keratoprosthesis design, surgery, and clinical management have undergone tremendous advancement over the past century [1]. Its modern-day use represents an important treatment for corneal blindness in conditions not amenable to traditional penetrating keratoplasty (PKP) [2]. While actual keratoprosthesis placement is traditionally done by a cornea specialist, the vitreoretinal specialist plays an important role in the preoperative, intraoperative, and postoperative management of keratoprosthesis patients [3, 4]. Although many types of keratoprostheses, or KPros, are in modern-day use worldwide, including the osteo-odonto-keratprosthesis (OOKP) [5], this chapter will focus on the Boston keratoprosthesis [6], one of the most widely used KPros in the world.

12.2 Preoperative Considerations

Proper patient selection is one of the most important criteria for favorable clinical outcomes given the commitment to lifelong topical medications, follow-up, and ever-present risk of postoperative complications [7, 8]. A multidisciplinary team of cornea, vitreoretinal, glaucoma, and oculoplastic specialists is ideally suited for preoperative planning and proper patient selection. Vitreoretinal and glaucoma specialists play an important role to best assess the visual potential of an eye with dense corneal opacity. The presence of a nasal

M.A. Klufas, MD • D.J. D'Amico, MD
S. Kiss, MD (✉)
Weill Cornell Medical College/NewYork Presbyterian Hospital, New York, NY 10021, USA
e-mail: szk7001@med.cornell.edu

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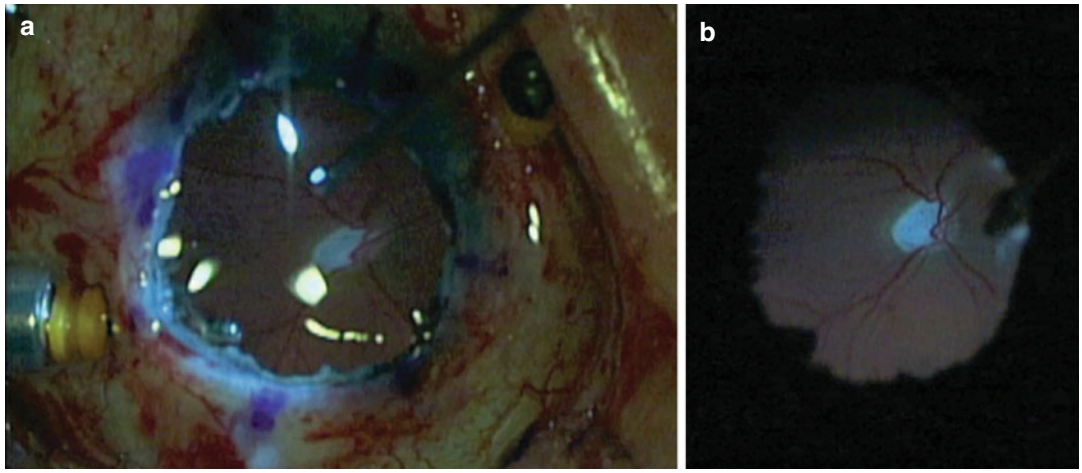

Fig. 12.1 Open sky fundus visualization. (**a**) Open sky view of posterior pole. (**b**) Visualization under the operating microscope is improved with the room lights dimmed and the light pipe placed into the anterior vitreous cavity

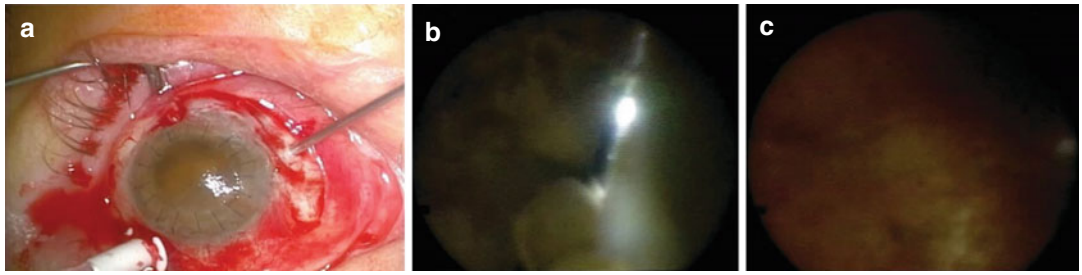

Fig. 12.2 Intraoperative endoscopy.(**a**) Endoscopy performed at the time of consideration of Boston KPro placement. (**b**) Vitreous debris and hemorrhage were initially encountered, and a vitrectomy was performed to improve visualization of the posterior pole and optic nerve to determine suitability for permanent Boston KPro placement. (**c**) After removal of vitreous debris, the status of the retina and optic nerve was deemed amenable for permanent KPro placement

projection of light can be a rudimentary but useful assessment of optic nerve function if severe glaucoma is suspected. B-scan echography by the vitreoretinal specialist may also detect the presence of an end-stage "cupped" optic nerve.

A more precise estimation of optic nerve and retinal visual potential may be accomplished under direct visualization during the placement of the KPro after the failed corneal graft has been removed (Fig. 12.1) or with endoscopy either at the time of KPro placement or in a separate surgical procedure prior to the KPro surgery itself (Fig. 12.2). Appearance of the optic nerve and retina may dictate how to proceed with additional surgery including permanent KPro placement. If the visual potential is deemed to be extremely poor, KPro placement may be abandoned, and a traditional penetrating keratoplasty may be performed. In such an eye, this simpler procedure will restore the ocular integrity while sparing the patient the intensive postoperative care and risks that would be incurred with KPro implantation. Identification of other retinal pathology such as retinal detachment or macular pathology will also influence intraoperative planning of initial KPro surgery.

12.3 Intraoperative Considerations

12.3.1 General Principles

Among centers that offer Boston KPro surgery, one major divide in the approach to initial KPro

surgery is the decision to perform KPro placement alone or, alternatively, in combination with other vitreoretinal or glaucoma procedures. Our center favors combined surgical procedures for several reasons: (1) removal of the native vitreous may decrease postoperative inflammation and inflammatory membrane formation; (2) placement of an aphakic Boston KPro with the removal of the crystalline lens and capsular bag may ultimately result in fewer long-term complications and facilitate any future retinal surgery; and (3) placement of a glaucoma drainage implant may be necessary given the high pre- and postoperative prevalence of glaucoma in many eyes that have come to require a KPro.

At the time of initial KPro placement, if the native corneal opacity permits a view, a vitrectomy many be performed followed by placement of the KPro by the corneal surgeon. If the patient's cornea is too opaque to permit a view, a temporary KPro may be placed, at the cost of adding time to the procedure. Perhaps the most appropriate option is to perform vitreoretinal surgery after the permanent Boston KPro has been placed – this is the most common approach taken at our center.

12.3.2 Vitreoretinal Surgical Pearls in the Setting of Keratoprosthesis

Though KPro eyes can be challenging, pars plana vitrectomy through a Boston KPro is safe without deleterious effects on the device. A two- or three-port vitrectomy may be utilized. A larger-gauge vitrectomy (20 Ga) has been reported in many published series [9]; however, microincisional vitrectomy surgery (MIVS) is also being increasingly utilized [4, 10]. Instrumentation size may dictate whether suturing sclerotomies are necessary and sutureless procedures may be performed [4].

Sclerotomies are placed 1–3.5 mm posterior to the limbus. If the limbus is not well defined, calipers may be used to measure 9 mm spanning the center of the Boston KPro optic in order to facilitate placement of trocars [3]. For the Boston type II (through-the-lid model), sclerotomies can be made directly through the eyelid (transcutaneous approach) with a microvitreoretinal (MVR) blade [3].

The role of scleral buckling in the management of keratoprosthesis remains limited, but may be a useful adjunct in select cases if used with caution given compromise of the anterior segment and scleral tissue secondary to KPro placement.

Both wide-angle contact lens [3, 4] and non-contact visualization systems such as binocular indirect ophthalmomicroscopy (BIOM) may be used [9] to visualize the fundus through the Boston KPro.

12.3.3 Indications for Vitrectomy

Studies report the incidence of vitrectomy after KPro placement at approximately 7 % [9]. Indications for vitrectomy in permanent keratoprosthesis include exploratory endoscopy, vitreous biopsy, glaucoma shunt placement/revision, retroprosthetic surgical membranectomy, retinal detachment repair, suprachoroidal hemorrhage drainage, surgery for endophthalmitis, epiretinal membrane removal, removal of intraocular inflammatory debris including proliferative vitreoretinopathy, hypotony, and removal of vitreous opacities including vitreous hemorrhage [3, 4, 9]. Management of some of these postoperative complications is discussed in further detail below.

12.3.4 Postoperative Management

Placement of permanent keratoprosthesis commits the patient and ophthalmology team to *lifelong* follow-up. This can be particularly challenging for patients who plan to travel to their native countries for months on end, especially to areas where ophthalmologists familiar with permanent keratoprostheses are not readily available. This further emphasizes a key metric of success in these devices is proper patient selection given the need for continued, close monitoring after device placement. Glaucoma and endophthalmitis are among the most common

and dreaded complications following Boston KPro surgery highlighting the need for multidisciplinary follow-up with a cornea, glaucoma, and vitreoretinal subspecialists.

Visualization of the fundus is possible with ordinary slit lamp biomicroscopy as well as binocular indirect ophthalmoscopy on a small pupil setting through the 2.8 mm diameter optic of the Boston type I KPro [11]. Visualization of the peripheral fundus can be challenging and is enhanced with ancillary testing including B-scan ultrasonography and ultra-widefield imaging. The Optos ® ultra-widefield scanning laser ophthalmoscope is one of the most reliable and widely used imaging modalities given its ability to image through the small-diameter optical column of the Boston KPro and quick acquisition time which is particularly helpful in low-vision patients even when nystagmus is present [12].

12.3.5 Postoperative Complications

The most common postoperative posterior segment complications after KPro surgery are retroprosthetic membrane, infectious endophthalmitis, sterile vitritis, and retinal detachment occurring on average 7.6 months after initial surgery [13]. Early identification and management of these complications minimizes visual morbidity.

12.3.6 Retroprosthetic Membrane (RPM)

Retroprosthetic membrane or RPM formation is one of the most commonly reported postoperative complications with an incidence between 14 and 77 % [14–20]. Risk factors for RPM formation include postoperative inflammation [14, 15], multiple additional surgical procedures at initial KPro surgery or postoperatively [15, 21], retinal detachment [22], infectious keratitis [20], and aniridia [20]. Histologically, RPM is composed of fibrovascular tissue [23] believed to originate from the host's corneal stroma, which grows through gaps in Descemet's membrane [24]. RPM may form as early as 1 week after KPro placement or many years after initial surgery [15, 21, 25].

Though RPM may form and remain visually insignificant, they may progress to visual significance or even contribute to KPro failure and chronic hypotony if progressive and exert traction over the ciliary body [26]. RPM has also been cited as a risk factor for retinal detachment [27].

RPMs that are not visually significant are best treated with observation, and those that progress should be treated promptly with a single-session YAG membranotomy [23]. Even with increased energy settings which can damage the KPro optic, YAG membranotomy may fail and necessitate surgical membranectomy (Fig. 12.3) [21]. From a practical standpoint, early management with a noninvasive YAG membranotomy is preferred to the more invasive intraocular surgery, which may be avoided if YAG membranotomy is performed before the membrane becomes too thick.

12.3.7 Infectious Endophthalmitis

Infectious endophthalmitis (IE) is the most dreaded KPro complication and often results in vision loss or loss of the eye. Given the Boston KPro never fully integrates with the host, there is a persistent communication between the nonsterile ocular surface and the sterile anterior chamber, resulting in a conduit for microbial invasion [28]. This complication may present weeks, months, and even years after placement of a KPro [29, 30]

Topical antibiotic prophylaxis is the single most important intervention in preventing endophthalmitis. With proper topical prophylaxis, including vancomycin, the incidence of bacterial endophthalmitis was 0.35 % per patient-year compared to 4.13 % in patients not receiving vancomycin [29]. Another large series with patients maintained on both vancomycin and a fourth-generation fluoroquinolone reported an incidence of 2.4 % or 0.014 infections per patient-year [30]. Other series using up-to-date prophylactic topical antimicrobial agents have

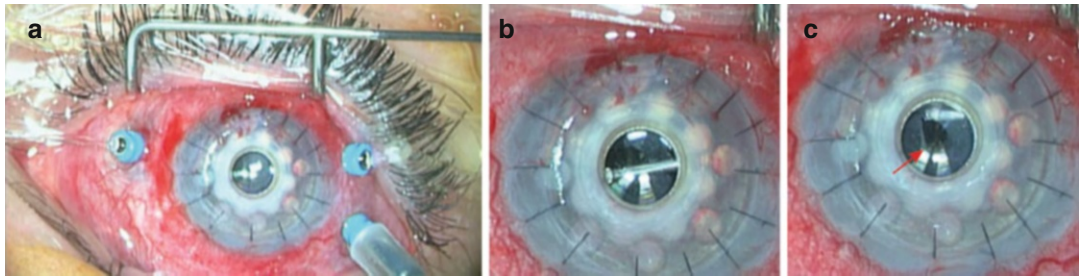

Fig. 12.3 Surgical membranectomy for retroprosthetic membrane. (**a**) Microincisional vitrectomy was performed for a dense retroprosthetic membrane that was not amenable to YAG membranotomy. (**b**, **c**) The vitreous cutter is used to remove the RPM from the backplate of the KPro and clear the visual axis (**c**). Intravitreal preservative-free triamcinolone was injected into the vitreous cavity after removal of the RPM

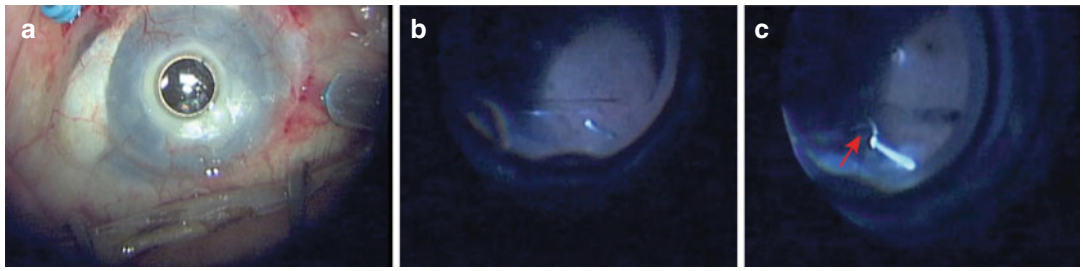

Fig. 12.4 Fungal endophthalmitis. (**a**) A three-port 25-gauge vitrectomy was performed for fungal endophthalmitis prior to removal of Boston KPro device and placement of cornea patch graft. (**b, c**) During surgery, numerous inflammatory vitreoretinal bands (*red arrow*) consistent with *Aspergillus* fungal endophthalmitis were identified and removed with vitrectomy

reported cumulative endophthalmitis rates of 6.7 % [31] and 7.1 % [32].

There is no universally agreed upon antimicrobial regimen at this time. Most KPro surgeons recommend lifelong topical vancomycin along with a fourth-generation fluoroquinolone for high-risk groups (e.g., autoimmune patients with ocular cicatricial pemphigoid or Stevens-Johnson syndrome), whereas non-autoimmune patients in favorable prognostic categories may be initially managed with a single-agent topical fluoroquinolone in the immediate postoperative period and then transitioned to polymyxin B/trimethoprim, which is inexpensive and provides broad-spectrum (including gram-positive) coverage.

Traditionally, the most common microbial organisms responsible for infectious endophthalmitis (IE) included gram-positive bacteria and less commonly gram-negative infectious. However, with the introduction of vancomycin prophylaxis, there has been a decrease in gram-positive infections and an apparent increase in fungal infections (Fig. 12.4) [33]. Causative microbial organisms are related to geographic location and climate, and, worldwide, infectious endophthalmitis is more common outside the United States [34].

Clinically IE presents with a sudden onset of decreased vision, eye redness, eye pain, and significant inflammation. On exam, fibrin and vitritis are often present; donor corneal edema and inflammatory retinal membranes or precipitates may also be seen [35].

The most important diagnostic evaluation of IE includes corneal culture and vitreous biopsy for identification of causative microbe. The mainstay of treatment is prompt injection of broad-spectrum intravitreal antimicrobials including vancomycin, amphotericin, and ceftazidime. Use of subconjunctival antibiotics is less common

[35]. The timing and use of intravitreal corticosteroids remains controversial, particularly with presumed fungal endophthalmitis [30], but may play an important role in decreasing ocular inflammation. Infectious disease specialists at our institution have often advocated for the use of intraocular steroids in the presence of fungal endophthalmitis as the use of amphotericin is not only fungistatic but also fungicidal, and when administered at appropriately high concentration, its mechanism of action is not impeded by concomitant intravitreal steroid use. Visual prognosis after IE is guarded and depends on the type of pathogen. One series reported 80 % of infected eyes lost useful vision, even after prompt treatment [29].

12.3.8 Sterile Vitritis

Sterile vitritis is an autoimmune phenomenon (to the device itself or corneal antigens released during tissue necrosis) and is best thought of as a type of uveitis [25]. Incidence ranges from 0 to 14.3 %, with many studies reporting rates less than 5 % [13, 15, 16, 18, 21, 22, 25, 34, 36–40]. In contrast to IE, patients present with *painless* vision loss without the characteristic injection and tenderness of IE [40, 41]. On examination, the eye typically appears quiet anteriorly with a dense vitreous cellular reaction often described as a "snowflake" pattern [42]. Onset is variable and may be months to years after surgery [13, 25, 41].

Given IE may also occasionally present with relatively little pain, sterile vitritis remains a diagnosis of exclusion with negative corneal and vitreous cultures. Sterile vitritis can be managed with peribulbar corticosteroids [41, 42] followed by intensive topical steroid therapy [35, 42]. Additionally, preemptive administration of intraocular antimicrobials should be considered if IE remains high on the differential diagnosis (especially while cultures and gram stain are pending). Outcomes in the setting of sterile inflammation are typically excellent with vision most often returning to baseline. No other preventative or prophylactic measures including the use of systemic steroids have been reported to be effective [40].

12.3.9 Retinal Detachment

Retinal detachment is a well-known complication of KPro surgery with a reported incidence of up to 16.9 % [3, 13, 15, 16, 18, 21, 22, 25, 34, 37–39, 43, 44]. Detachments can be rhegmatogenous or tractional [13, 45] and occur secondary to retinal breaks and/or proliferative vitreoretinopathy oftentimes in response to chronic inflammation [3]. This complication may occur months to years after KPro surgery [15] and occurs more frequently in eyes that that have undergone YAG membranectomy for RPM (26.7 % versus 5.7 %) [13].

Diagnosis is often initially made in the outpatient setting, but clinically, best visualization is achieved in the operative room [3, 46]. Vitrectomy with long-acting gas or silicone oil tamponade is the most frequently used surgical approach [13, 15]. Repair of retinal detachment in the setting of KPro is challenging given the preponderance of other retinal pathology including epiretinal membranes, proliferative vitreoretinopathy, subretinal fibrosis, and vitreous adhesions. Even with successful anatomic outcomes, visual outcomes are often variable, with several series reporting no visual improvement in over 50 % of patients after retinal detachment repair [3, 39].

Conclusion

Keratoprosthesis surgery has undergone significant improvements over the past several decades, which has improved outcomes and expanded indications for this treatment of severe corneal pathology. Nevertheless, preoperative evaluation, placement of the KPro, and postoperative management remain challenging for the multidisciplinary ophthalmology team caring for these complex eyes. Given the concurrent posterior segment pathology that may be present at any time, the vitreoretinal specialist plays an important role in identifying and treating conditions that may lead to vision

loss. Continued advancements in ancillary testing including imaging technology as well as vitreoretinal surgical instrumentation and techniques will continue to improve outcomes in the setting of permanent keratoprosthesis.

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Management of Complications During Vitrectomy for Macular Surgery

13

Fabio Patelli and Stanislao Rizzo

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F. Patelli (✉)
Department of Ophthalmology, San Paolo Hospital, University of Milan, Milano, Italy
e-mail: fabio@patelli.it

S. Rizzo
Department of Ophthalmology, Azienda Ospedaliera "Careggi", University of Florence, Italy

13.1 Introduction

Macular surgery includes different pathologies such as macular pucker, macular hole, macular edema, and others affecting the macular area. The new vitreoretinal technologies permit now a faster and safer surgery with high percentage of anatomical and functional results. Nevertheless, like every surgery, macular surgery isn't free of complication, and it is important to know them in order to avoid or manage possible retinal impairment.

13.2 Surgical Macular Pathologies

Vitreous is an important anatomical structure with role in ocular physiology. With age biochemical changes occur so that vitreous starts to liquefy. Once the vitreous is liquefied (synchysis), it collapses and passes in the retro-hyaloid space (syneresis). In complete posterior vitreous detachment (PVD), besides synchysis, there is a weakness of the adherence between the posterior cortex and ILM with total detachment of the posterior cortex. Abnormal adhesions are associated with incomplete PVD, and it is the trigger of a lot of retinal pathologies: epiretinal membrane, macular hole, tractional macular edema, myopic traction maculopathy, and exacerbations of exudative macular degeneration.

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13.2.1 Epiretinal Membranes

Idiopathic epiretinal membrane (ERM) is a common disease affecting 2 % of patients under 60 years of age and 12 % in those older than 70 years [1]. The pathogenesis of ERMs is not well known. The most recent hypothesis states that collapse of the liquefied vitreous body without sufficient dehiscence at the vitreoretinal interface can induce a split within the posterior vitreous cortex (vitreoschisis), leaving the outermost layer of the posterior vitreous cortex attached to the macula [2]. Patients may be asymptomatic or complain of metamorphopsia and blurring of varying severity. On examination, the epiretinal layer can be seen as a glistening membrane overlying the fovea, often associated with retinal striae in a radial fashion and macular thickening. Contraction of the membranes can also cause retinal vascular distortion. More severe ERM can cause loss of the normal foveal reflex and pseudohole formation. The treatment of epiretinal membranes is either observation or surgery when the ERM starts to affect vision [3, 4].

13.2.2 Macular Hole

Idiopathic macular holes (IMHs) are round full-thickness vertical retinal defects in the foveal neurosensory retina [5, 6]. Recent research (using ultrasound and OCT) has elucidated that IMHs are initiated during perifoveal PVD as a consequence of anteroposterior and dynamic VMT [7–9].

In total, ~55 % of patients presenting with IMH exhibit VMT to the edges of the IMH, with 67 % of stage 2 holes having VMT, but very few with stage 3 IMH having persistent VMT [6].

A small early IMH has the capacity to repair itself after complete VRI separation via proliferation of retinal glial cells [9].

Paradoxically, if this repair mechanism fails, glial cells migrating to the edge of the hole can progressively contract, resulting in its enlargement. The edge of the IMH subsequently becomes progressively elevated by a cuff of subretinal fluid that may be accompanied by thickening of the neurosensory retinal tissue [10].

A variety of traumatic events including blunt trauma, phototoxicity, spontaneously resolved VMT/IMH, and other unrecognized causes can cause localized outer retinal defects, which appear as tiny (50–100 μm) apparent foveal microholes.

The inner retina remains intact and the condition is nonprogressive, occurring in patients of all ages. The visual acuity is often good although the patient may be aware of a central scotoma [11].

Few studies have specifically investigated the epidemiology of idiopathic VMT, due to its overlap with many other ocular disorders and abnormalities. However, it has been estimated that the prevalence of VMT in isolation from IMH is ~22.5 per 100,000 of the general population, while the incidence is estimated as 0.6/100,000 per year [12].

In observational and interventional studies, the mean age of patients diagnosed with VMT is around 65–75 years (range ~48–83 years), with a predominance of females [13–16]; IMH predominantly occurs in individuals aged >65 years [8, 17, 18].

The prevalence of IMH has been estimated at around 0.1–0.8 % of adults aged >40 years, while the age-adjusted incidence has been reported as 7.8 per 100,000 of the general population per year. Approximately two-thirds of patients are women and the condition is unilateral in around 80 % of cases [19].

Success rates in terms of closure for IMH with vitrectomy are generally high (reported 85–100 %); however, a number of IMH characteristics are thought to impact on successful closure following PPV. These include a smaller base diameter, smaller inner opening size, and shorter minimum linear dimension [20–23].

13.2.3 Diabetic Tractional Macular Edema

Diabetic macular edema (DME) is one of the most common causes of visual loss in patients with diabetes mellitus [24]. Estimates of the prevalence of DME vary [25]. In a Danish population, a 9.6 % overall prevalence was reported,

including 7.9 % for type 1 diabetes and 12.8 % for type 2 diabetes [26].

In a long-term US study, the incidence of DME over a 10-year period was 20.1 % for "younger-onset" patients (those diagnosed before 30 years of age), 25.4 % for "older-onset" patients using insulin, and 13.9 % for "older-onset" patients not using insulin [27]. The pathophysiology of DME involves dilated capillaries, retinal microaneurysms, and loss of pericytes, with eventual impairment of the blood-retinal barrier (BRB) [28]. Breakdown of the BRB results in fluid leakage into the extracellular space, which disrupts macular structure and function on a cellular level [29, 30].

The vitreous has been implicated as a cause of macular edema in people with diabetes via several mechanical and physiologic mechanisms, all of which are postulated to lead to increased vascular permeability [31–35].

The observation that release of mechanical traction on the macula with subsequent reduction in DME, either by spontaneous posterior vitreous detachment or with vitrectomy, leads support to this line of reasoning that the vitreous is implicated as cause of macular edema [36–38].

Furthermore, the evidence that increased oxygenation can reduce DME suggests an additional physiologic advantage, potentially conferred by vitrectomy [39].

Removal of the epiretinal membrane (ERM) at the time of vitrectomy was associated with somewhat better visual acuity outcome, but no relationship was found with the degree of retinal thickness reduction, potentially reflecting resolution of distorted vision from ERM rather than resolution of DME.

Removal of the ILM at time of vitrectomy was associated with somewhat greater reduction in retinal thickness, but no association was found with visual acuity improvement.

Few previous reports in the literature have evaluated factors associated with visual acuity or anatomic outcomes after vitrectomy for DME. In a retrospective study of 486 eyes that underwent vitrectomy and lensectomy for diffuse non-tractional DME, Kumagai et al. [40] found that visual outcomes with ILM peeling were better than those associated with preservation of the ILM in a univariate analysis.

13.2.4 Myopic Tractional Maculopathy

Pathologic myopia is a leading cause of visual impairments [41, 42].

In highly myopic eyes, the elongation of the axial length of the eye and the development of a posterior staphyloma result in thinning of the retina and choroid, which then leads to the development of different types of myopic traction maculopathy [43].

Important causative factors might be related to the tangential traction caused by a premacular membrane or fibrosis and the inverse traction caused by the posterior staphyloma [44, 45].

The treatments are mainly based on surgery, including vitrectomy and scleral reinforcement surgery in order to relieve the retinal traction. The options of specific surgery procedures are still under debated.

Myopic macular schisis is a relatively common finding in eyes with high myopia, and the prevalence increases with the degree of myopia. Mild cases do not necessarily impact visual acuity, whereas severe cases usually affect vision. In mild to moderate cases, no treatment is warranted. However, in severe cases with progressive visual loss, vitrectomy can improve both the anatomy and the vision.

Myopic tractional retinal detachment is an uncommon occurrence; the underlying mechanism is not entirely clear, but tractional forces are thought to be the predominant factor. The presence of a large neurosensory detachment of the retina, isolated to the macula, is present. There are often associated vitreous membranes with tractional insertions on the detachment. Other pathologic features of high myopia are usually present such as posterior staphyloma, macular schisis, and/or macular hole.

13.2.5 Optic Pit Maculopathy

An optic disk pit is a congenital abnormality of the optic nerve head, first described in 1882 by Wiethe1 as a gray, white-yellow, or black round depression in the optic disk [46].

Optic disk pits are extremely rare, with an incidence of 1 in 11,000 [47].

In 1927, Halbertsma described an association of optic disk pit with macular lesions and poor visual acuity, which is now known as optic disk pit maculopathy (ODP-M) [48].

ODP-M can develop in 25–75 % of optic disk pits and usually confers a poor visual prognosis, with 80 % of eyes having a final visual acuity of 6/60 or worse, as a result of long-standing serous macular detachment, formation of macular holes, and atrophy of the underlying retinal pigment epithelium [49].

The morphology of ODP-M has been well characterized by the use of optical coherence tomography (OCT). ODP-M has a typical bilaminar appearance of retinal schisis and neurosensory detachment, but, commonly, either one of the features exists in isolation. Outer retinal holes and dehiscence are uncommon findings in ODP-M and reported to occur in only 27 % of cases [50].

13.3 Complications During Macular Surgery and Management

In every step of macular surgery, a complication can occur. The surgeon should know the possible complications in order to prevent and manage them and reach the correct outcome of the surgery.

13.3.1 Complications During Trocar Insertion

Wound construction is critical in microincision vitrectomy surgery. The three main steps in constructing a proper wound include displacing the conjunctiva away from the sclera, flattening the sclera on insertion, and angling the incision. Each one of these steps helps create wounds that will not leak. Misaligning the conjunctiva from the scleral hole prevents a vitreous wick from extending external to the conjunctiva. Flattening the sclera on trocar insertion provides a longer wound cord length, which is less likely to leak, and angling the incision has been proven to seal better in both anterior and posterior segment incisions. When you make an angled incision, you initially insert the blade at a 30° angle (at least). This will make the wound more stable because it is less likely to cause internal disruption of the wound edges. These three basic steps are simple, but very important to follow when constructing a microincision wound in order to limit postoperative complications including wound leakage, gas leak, hypotony, and endophthalmitis.

One of the more frequent complications is the incorrect trocar insertion. In a phakic patient, it could happen that during the insertion, the trocar is bended by the surgeon and can touch the lens and break the posterior capsule. It is rare that the lens become immediately opaque and the macular surgery can be continued without any problem. If the lens opacity is an obstacle for the macular surgery procedure, it is better to remove the lens via the pars plana with vitrectomy and insert the intraocular lens (IOL) in the sulcus on the anterior capsule.

If the trocar insertion is too far from the corneal limbus (more than 4 mm), it can go under the retina and create a retinal break/detachment. When it happens, the trocar must be removed and repositioned in another site, and the case must be treated as a retinal detachment case.

If the trocar insertion is too close to the corneal limbus (less than 2.5 mm), it can touch the ciliary body and create a vitreous bleeding. Usually bleeding from the ciliary body is difficult to manage. One of the choices is to stop the surgery and wait days or weeks that the bleeding stops and then perform a vitrectomy as programmed. Another choice is to continue the surgery and try to stop the bleeding using diathermy, but sometimes this is very difficult to do because it is not easy to find the bleeding point of the ciliary body.

13.3.2 Complications During Posterior Vitreous Detachment

Posterior vitreous detachment is a critical step during vitrectomy. The most common complication during posterior vitreous detachment is iatrogenic retinal break (Fig. 13.1). Secondary

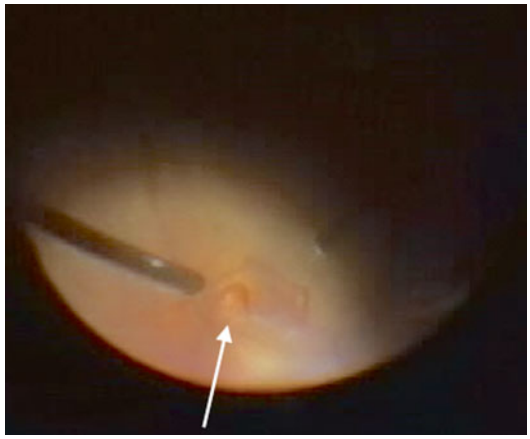

Fig. 13.1 Peripheral retinal break (*arrow*) during vitrectomy caused by vitreous traction

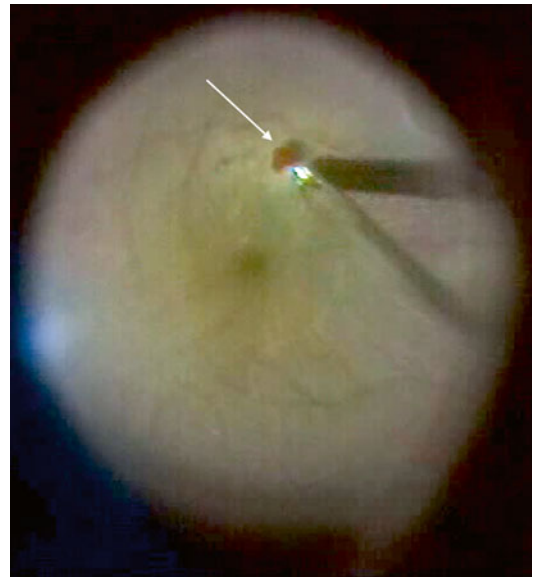

Fig. 13.2 Epiretinal bleeding (*arrow*) during ILM peeling in macular pucker

retinal detachment caused by intraoperative iatrogenic retinal breaks remains the most common sight-threatening complication of this surgery despite the recent advances in wide-angle viewing systems and instrumentation [51–54]. The frequency of iatrogenic retinal breaks during PPV has been reported to range from 0 % to 24 % with post-PPV retinal detachment occurring 0–15.8 % [53, 55–65].

Absence of preoperative PVD was significantly associated with higher frequency of iatrogenic retina breaks [66]. There is a strong association between surgical induction of PVD and the frequency of iatrogenic breaks in eyes undergoing pars plana vitrectomy (PPV) [67, 68]. At the end of every macular surgery, an accurate check of the peripheral retina is a must in order to find missing iatrogenic retinal breaks and treat them with cryo or laser as usual.

13.3.3 Complications During Peeling

Membrane peeling and internal limiting membrane (ILM) peeling are the topic and more delicate maneuvers during macular surgery. Different dyes on the market nowadays helps to better and safer perform this maneuver; nevertheless, some complications can occur during peeling.

ILM peeling can be performed by making a small opening and a flap tear in the ILM with a bent Microvitreal - retinal blade. The ILM flap is then grasped with end-gripping forceps and carefully started in a circular capsulorhexis maneuver [69]. In another technique of ILM peeling, the membrane can be removed by directly grasping the membrane with end-gripping forceps, without creation of a flap [70]. The reported complications associated with ILM peeling are postoperative hyphemas and retinal incarceration into the silicone soft-tip aspirator [71].

One complication of peeling is bleeding (Fig. 13.2). Epiretinal or subretinal bleeding can occur during peeling above all during ILM peeling that is usually strongly adherent to the retina. When the ILM is stretched over a vessel, it can bleed. When this complication occurs, the surgeon should immediately raise the intraocular pressure (IOP) up to at least 60 mmHg in order to stop the bleeding. If it occurs over the retina, the blood clot can be easily sucked by the vitrectomy probe, and if the vessel continues to bleed, it is helpful to touch it with the end of the vitrectomy probe and push gently for few seconds. Usually the vessel stops to bleed with this simple maneuver. If the bleeding is under the retina, raising the IOP is mandatory. The surgery can be continued and at the end a fluid-gas exchange is suggested. A prone position of the patient for 1–2 days can help the blood displacement far away from the

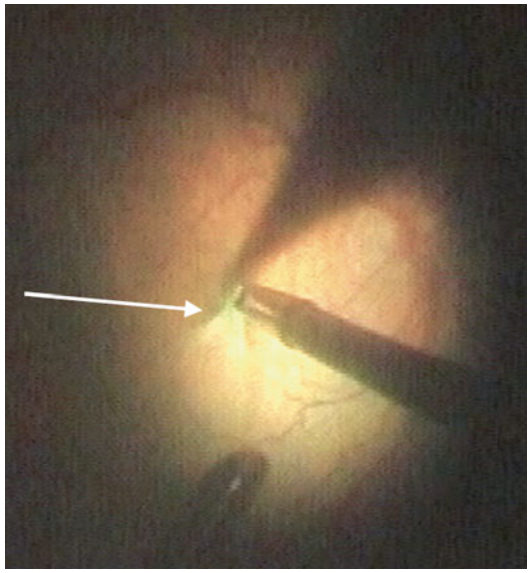

Fig. 13.3 Accidental retinal peeling with forceps (*arrow*)

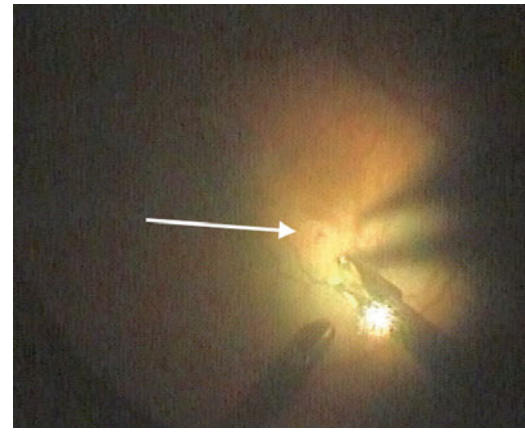

Fig. 13.4 Retinal break (*arrow*) in the macular area caused by forceps during peeling

macula area. If there is a macular hole, the under-retina blood could be spontaneously evacuated from the hole; to suck it using a back-flush is not a good procedure because the hole can enlarge. If the under-retina bleeding occurs in a pucker or macular edema, in order to facilitate the blood displacement, it could be useful to detach the macula using balanced salt solution (BSS) injection under the retina through a 41-G needle.

Another not so infrequent complication is retinal break in the macula during peeling (Figs. 13.3 and 13.4). It can occur for the strong adherence of the membrane to the retina or more frequently directly by the forceps. Macular breaks don't need to be treated by laser because laser can damage the visual acuity and also a retinal detachment from a macular break is very rare to occur. What we suggest if it happens is to leave it and continue the procedure as programmed.

On the opposite, if a posterior retinal break occurs during peeling in high myopic eyes, it should be laser treated and tamponated using air or gas at the end of the surgical procedure.

Iatrogenic macular hole could happen during ILM peeling for macular edema. If it happens, it should be treated as a macular hole with gas injection at the end of the procedure. In order to avoid it, the peeling must be in a centripetal way and very slowly manner.

Another complication reported by Karacorlu et al. during ILM peeling is "iatrogenic punctate chorioretinopathy" [72]. This is an unintentionally chorioretinal lesion created during grasping the ILM with end-gripping forceps. In this study, fluorescein and indocyanine green angiographic findings indicate that iatrogenic punctate chorioretinopathy affects the choriocapillaris as well as the RPE. Choroidal neovascularization did not develop, and the lesion remained unchanged during follow-up.

13.3.4 Complications During Fluid-Air Exchange

Fluid-air exchange is a very important step in macular surgery above all in macular holes. The most common complication is the opacity of the posterior capsule of the IOL in pseudophakic eyes caused by air. If the opacity occurs, there are two possible solutions: (1) inject through the trocar some viscoelastic over the posterior capsule of the IOL, and (2) turn air into BSS and direct the infusion cannula against the posterior capsule. The BSS can clean the posterior capsule from the fogging; then, turn again the infusion into air and complete the exchange.

13.3.5 Gas Injection Technique and Management of Complications

There are different techniques for intraocular gas injection as the last surgical procedure after macular surgery. The one we use is injecting the air-gas mixture through the cannula. Once one trocar is removed, the air-gas mixture siring is connected to the cannula. While it is manually injected into the eye through the cannula, a back-flush needle is inserted in the other trocar in order to permit the air to come out. In this maneuver, the only complication is hypotony once the cannula is removed, because the scleral wound can remain open. If this happens, the surgeon should close the sclerotomy and inject air-gas mixture through the pars plana with a 30-gauge needle until the eye pressure is normal.

Conclusions

In this chapter, we tried to include all the possible complications during macular surgery. In every surgery, all the steps of the procedure can potentially encounter complications. The most common complications are iatrogenic retinal breaks during vitrectomy or, less common, during peeling. The expert surgeon should know how to avoid and treat these complications for the good surgical outcome.

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14 Management of Complicated Vitreoretinal Diseases Using Minimally Invasive Vitrectomy Systems

Yusuke Oshima

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Since Dr. de Juan introduced the current concept of transconjunctival sutureless vitrectomy with a trocar-cannula system and small-gauge instrumentation, [1] numerous advances in the technologies and techniques have brought about a dramatic change in the landscape of pars plana vitrectomy over the past decade. As a result, transconjunctival microincision vitrectomy (MIVS) using small-gauge (23- or 25-gauge) instrumentation has emerged as a global standard surgical style of vitrectomy for treating a variety of vitreoretinal pathologies, with offering numerous benefits over the conventional 20-gauge system including shorter operating time, reduced corneal astigmatism, diminished conjunctival scarring, improved patient comfort, and, in some cases, earlier visual recovery. Thanks to the recent advances in developing high-end multifunctional vitrectomy machines and ultrahigh-speed cutters, powerful illuminating light sources and chandelier endoillumination systems, and wide-angle viewing systems (WAVs), several new techniques have been developed and enabled using much smaller-gauge systems for treating challenging cases safer and more efficient. In the current article, we are describing the state-of-the-art surgical settings and techniques in vitrectomy, membrane manipulations, and fundus visualizing with small-gauge vitreous surgery systems along with the recent advances in technologies.

Y. Oshima, MD
Oshima Eye Clinic, Vitreoretinal and Cataract Surgery Center, Takatsuki-city, Osaka, Japan
e-mail: yusukeoshima@gmail.com

14.1 Importance of Chandelier Illumination in Challenging Cases

The basic advantage of using chandelier endoillumination is the illumination safety during surgery. When considering retinal phototoxicity, the working distance for light irradiation is important, and holding the light probe as far away from the retina as possible increases safety,

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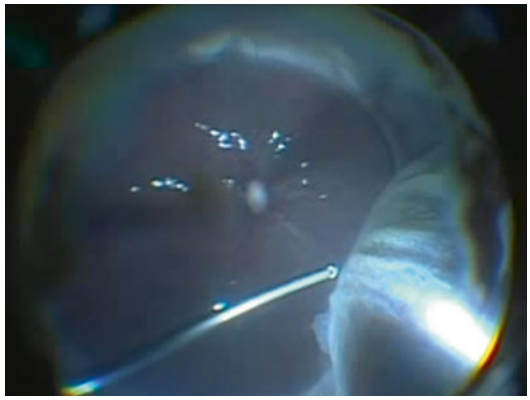

Fig. 14.1 Self-retaining chandelier endoillumination can free one hand for scleral indentation, and thereby surgeons will achieve more controlled and smooth peripheral vitreous base shaving by themselves without the need for an assistant

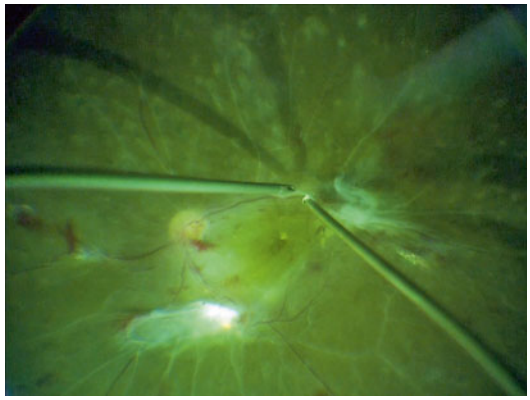

Fig. 14.2 In more challenging cases, the freed hand is helpful for holding forceps to grasp membranes for separation from the retina or for dissection using scissors or a cutter in a bimanual procedure. Setting the chandelier fiber superiorly is helpful, making the shadow go down to the inferior area, which can help in avoiding the instrument shadow coming into the working zone

especially in the challenging cases needing a long operating time. In addition to the safety advantage, the self-retaining nature of chandelier endoilluminators frees up my hand from holding a light probe, allowing true bimanual manipulation during surgery. In retinal detachment cases, chandelier illumination makes us perform scleral indentation and achieve more controlled and smoother peripheral vitreous base shaving without the need for an assistant (Fig. 14.1). For membrane dissections in challenging cases, such as diabetic tractional retinal detachment or proliferative vitreoretinopathy, the freed hand is helpful for holding forceps to grasp the membranes for separation from the retina or for dissection using scissors or a cutter (Fig. 14.2). For cases in which a self-retaining chandelier system is used, setting up the fiber superiorly is recommended, e.g., a single fiber at 12 o'clock or dual fibers at 2 and 10 o'clock, to make the instrument shadow appear anteriorly and not interfere with the working area view. Not only is it easy to adjust the optic fiber tips from this angle, but illumination is optimized, and glare from the tips of the instruments is minimized. The direction of illumination can be changed from the posterior pole to the periphery by changing the curvature of the chandelier fiber outside the orbit (Fig. 14.3). The WAVs revived in recent years have further facilitated the currently widespread use of microincisional approaches for pars plana vitrectomy. Using WAVs, the full extent of the vitreous base, where residual traction often causes surgical failure, can be exposed and accessible for surgical manipulation, even using small-gauge instruments with less need for scleral indentation.

14.2 Technologies and Techniques in Vitreous Cutting

Most of the recently developed vitrectomy machines feature high-speed cutters with its cutting rates over 5,000 cpm. The high cutting speed keeping the duty cycle over 50 % has dramatically improved the vitreous cutting efficiency of small-gauge cutters even with 25 gauge or much smaller 27 gauge [2]. This advancement has facilitated lots of surgeons making a transition to smaller-gauge instrumentation for MIVS in recent years (Fig. 14.4).

In addition to the improvement of the conventional spring pneumatic-driven vitreous cutter, the dual pneumatic valve-driven vitreous cutter (ULTRAVIT® probe, Alcon Laboratories) is a new concept for vitrectomy, which is currently capable to have a ultrahigh-speed cutting up to

Fig. 14.3 The direction of the illumination focusing on the posterior pole (**a**) or periphery (**b**) can be optimized easily by changing the curvature of the chandelier fiber outside the eyeball with this flexible type of chandelier fiber

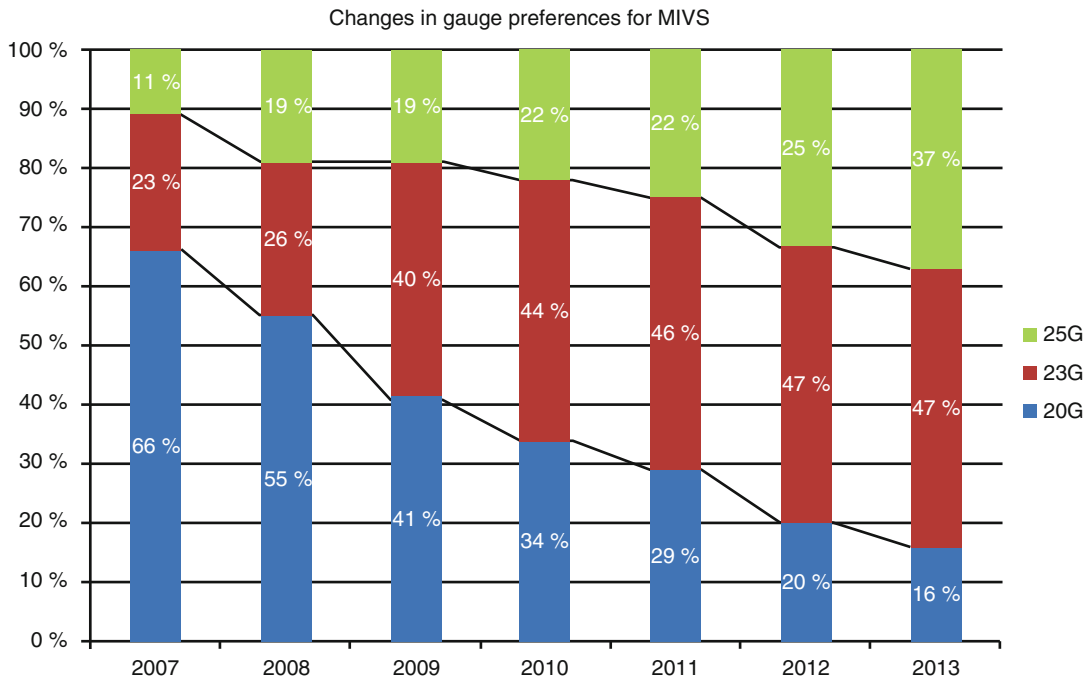

Fig. 14.4 Global survey of surgeons' preference of gauge over years

7,500 cpm with duty cycle controls in a variety of situations (Fig. 14.5) in corporation with the CONSTELLATION Vision System® (Alcon Laboratories). The elegant mechanism that increases or decreases flow without changing the cut rate or vacuum parameters may facilitate more efficient core vitrectomy and safer peripheral vitreous shaving with less traction force to the retina [3]. With the latest program featured in the CONSTELLATION Vision System®, two different cutting and aspiration settings can be set sequentially by the foot pedal control along with the percentage of step-in based on the surgeons' preference as shown in Fig. 14.6. It is very convenient to perform efficient core vitrectomy with full step-in of the treadle and safer

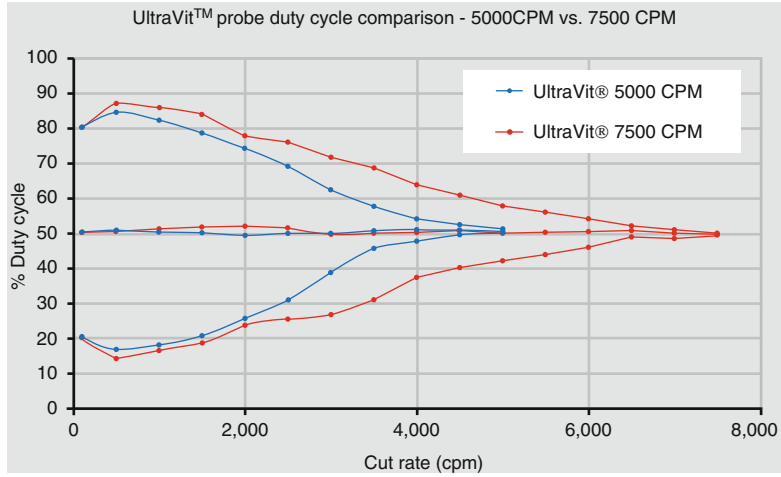

Fig. 14.5 Comparison of duty cycle changes of the dual pneumatic-driven cutter (5,000 cpm vs. 7,500 cpm). The definition of duty cycle is the ratio of the time the port is open in a cut cycle to the overall duration of the cut cycle, which is presented as a percentage. The CONSTELLATION Vision System® has three settings called "core" (port biased open), "shave" (port biased closed), and 50/50. The open biased setting renders the port mostly open in the cutting cycle, maximizing flow for the given cut rate and vacuum. The closed biased setting renders the port mostly closed in the cutting cycle, minimizing flow and traction force for the given cutting rate and vacuum. The reduced bite size at higher cut rates reduces the resistance to flow and increases the flow rates

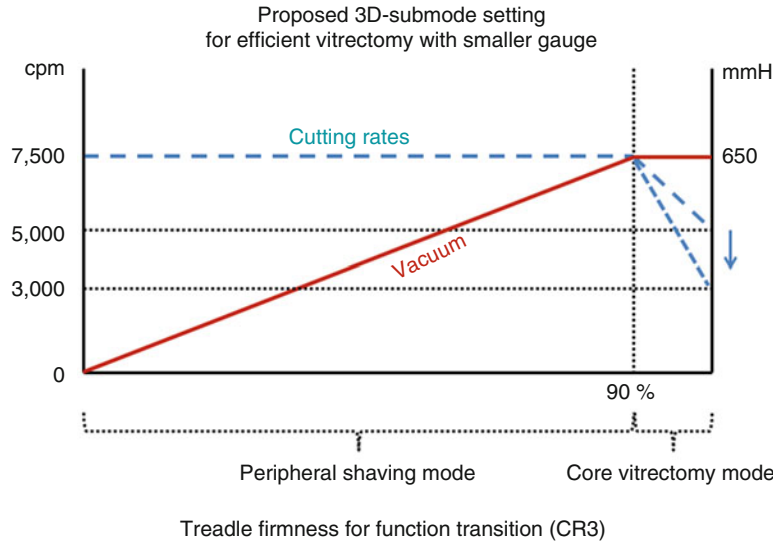

Fig. 14.6 A proposed 3D submode setting for efficient vitrectomy. Core vitrectomy is capable by full step-in of the foot pedal to keep the maximum aspiration of 650 mmHg with higher duty cycle cutting rates of 5,000 cpm, and a safer peripheral vitreous shaving is achievable sequentially by simply releasing the foot pedal to get a proportional control of the aspiration with the highest cutting rates of 7,500 cpm

peripheral vitreous shaving sequentially by simply releasing the treadle slightly, especially suitable for the cases with retina detached or mobile even with the currently smallest small-gauge system of 27-gauge (Fig. 14.7).

Another concept of a double-port cutter featuring a second port in the internal guillotine blade of the cutter has been developed to incorporate into the spring pneumatic-driven cutter to improve the flow efficiency in a small-gauge cutter by keeping the duty cycle without attenuation along with increasing the cutting rate [4, 5]. This approach may be another step forward to improving the flow efficiency during small-gauge vitrectomy. However, further studies are still warrant to evaluate the potential risk of

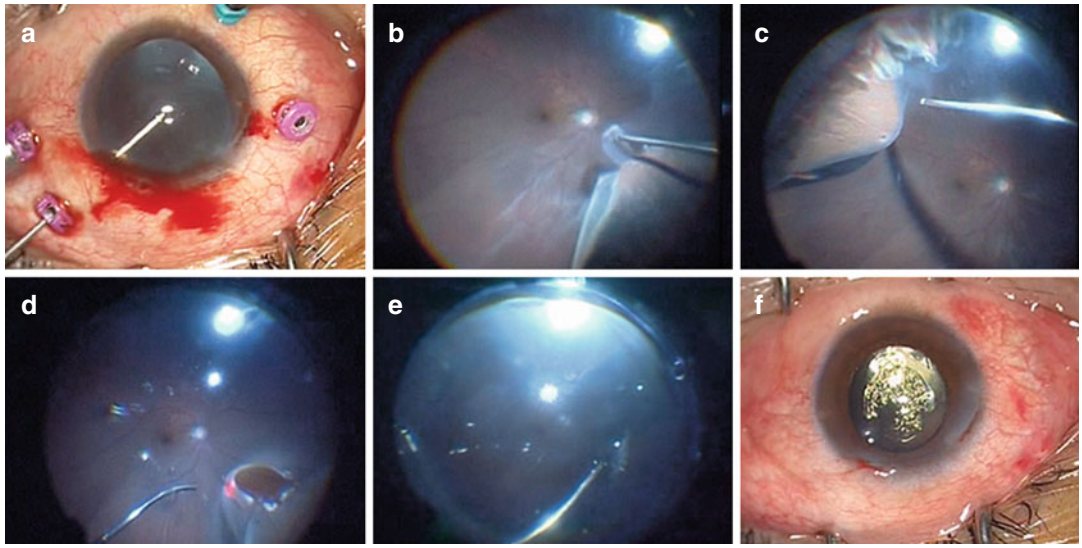

Fig. 14.7 A 27-gauge vitrectomy system for treating rhegmatogenous retinal detachment. **(a)** A 27+® valved cannula (*purple*) system with a 25-gauge cannula-compatible chandelier illumination fiber (*light green*). **(b)** Releasing the vitreous traction around the retinal break with a 27+ ULTRAVIT® probe at 7,500 cpm. **(c)** Peripheral vitreous shaving under scleral indentation. **(d)** Endophotocoagulation around the retinal break with a 27+ curved laser probe. **(e)** Fluid-air exchange performed with a 27+ soft-tip back-flush needle probe. **(f)** Surgical view at the occlusion of 27+ vitrectomy after cannula removal

increasing the traction force on the vitreous with this type of cutter because of the cutting port almost being fully opened.

14.3 Techniques for Membrane Removal

14.3.1 Cutter Techniques

Several studies have proved transconjunctival MIVS to have several advantages over conventional 20-gauge instrumentations for diabetic vitrectomy [6–8]. The conjunctiva-preserving nature of MIVS allows repeated vitrectomy or filtering surgery that may be needed in patients with diabetes complicated with neovascular glaucoma, even after vitrectomy. The surgical techniques for removing diabetic fibrovascular membranes during MIVS differ from those in conventional 20-gauge vitrectomy. Because the distances from the ports to the tips in the small-gauge vitreous cutter are shorter than those of a conventional 20-gauge vitreous cutter, the cutters can serve as multifunctional tools during membrane removal. The port of the 23-, 25-, or 27-gauge cutters can be inserted readily between the fibrovascular membrane and retina, allowing successful membrane segmentation, dissection, and removal using a small-gauge vitreous cutter only. Therefore, we have lower chance to use complex instruments such as scissors, pick, and spatula for fibrovascular membrane removal in most cases.

Several different techniques using a small-gauge cutter for membrane dissection have been proposed by Dr. Steve Charles as "cutter delamination" [9]. The "foldback delamination" (Fig. 14.8) is a very useful and safe technique for removing flexible, weakly fixed membranes by putting the cutter port just behind the membrane's leading edge and folding back the membrane into the port with high-speed cutting in shave mode with gentle aspiration. The membrane existing between the cutter port and the retina may reduce the potential risk of making iatrogenic breaks.

The thickened fibrovascular membranes, large blood clot, and retained lens fragments can also be engaged and cut off by the small-gauge cutter along with the reduced cut rates (Fig. 14.9). In the cases with thickened membranes, I prefer using

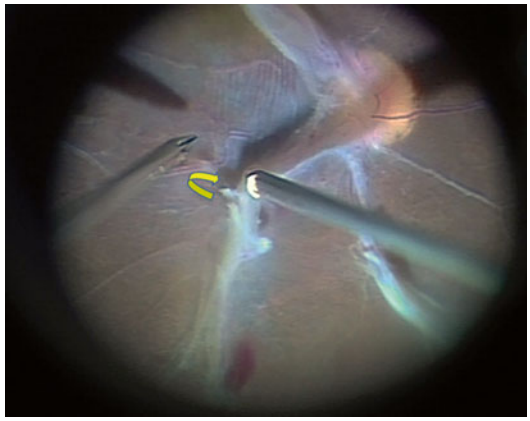

Fig. 14.8 Foldback membrane delamination with a 25-gauge cutter. Placing the cutter port just behind the membrane's leading edge and folding back the membrane into the port (*yellow arrow*) with high-speed cutting in shave mode with gentle aspiration

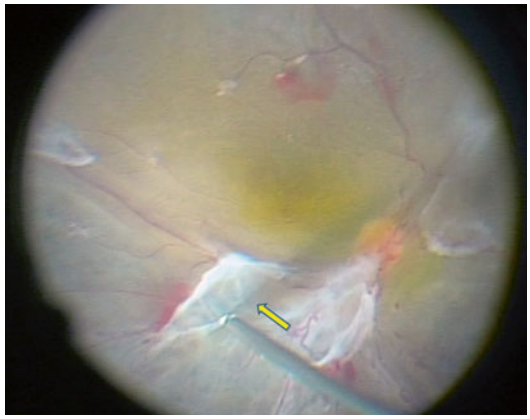

Fig. 14.9 Conformal membrane delamination with a 25-gauge cutter. The thickened membrane can be dissected directly by moving the cutter port forward into the leading edge of membrane (*yellow arrow*) while adjusting the port away from the retina to reduce the risk of the retina entering the port

the "conformal cutter delamination" technique proposed by Dr. Steve Charles as well. The thickened membranes can be dissected directly by moving the cutter port forward into the leading edge of membranes with adjusting the port away from the retina to reduce the risk of retina entering the port. In conjunction with the latest program featured in the CONSTELLATION Vision System®, the current two cutter delamination settings can be customized sequentially as shown in Fig. 14.10 (personal communication with Dr. Osawa from Iga, Japan). You can switch the two different techniques quickly by rotating and/or repositioning the cutter port while changing your step-in percentage to control the preferred cutting setting depending on the thickness and fragility (OR: fragility) of the fibrovascular membranes.

14.3.2 Tips and Indications for Bimanual Maneuvers

The current widespread use of chandelier endoillumination in conjunction with a wide-angle viewing system has improved the ability of performing bimanual intraocular manipulation with small-gauge instruments for challenging cases [10]. Under panoramic viewing, we no longer need to move the globe with surgical instruments to see the periphery; thus, we have far fewer feelings of frustration over the fragility of the small-gauge instrument during vitrectomy [11]. In addition, chandelier endoillumination allows the surgeon to have one hand free to manipulate and depress the globe. These two advances have facilitated quicker, safer, and more thorough removal of the membranes from the detached or mobile retina bimanually with small-gauge instruments. Although in most cases the membranes can be peeled, dissected, and removed with a single hand because of the multifunctionality of the small-gauge cutter, patients with combined traction and rhegmatogenous retinal detachment due to extensive fibrovascular membranes or those with proliferative vitreoretinopathy (PVR) accompanied by strongly adhesive pre- and/or subretinal membranes are well indicated for bimanual membrane dissection and/or peeling in small-gauge vitrectomy.

In diabetic cases, we usually use a membrane forceps with a vitreous cutter to grasp and dissect the broad sheet of membrane. Under panoramic viewing, the membrane forceps allows us to engage easily the edge of the membrane to introduce more easily the blunt tip of a small-gauge cutter into the tight space between the detached retina and adherent membranes (Fig. 14.11). The combination of forceps with curved scissors can be another option. Although surgically adjunctive

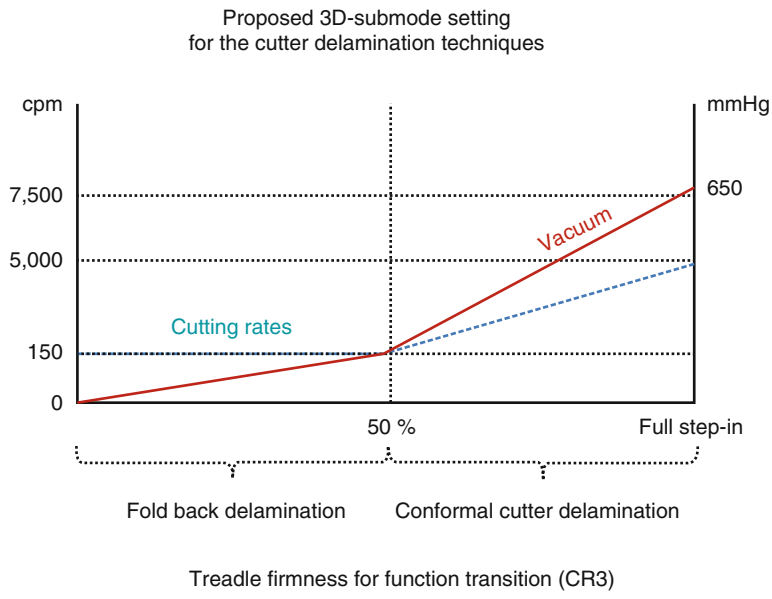

Fig. 14.10 A proposed 3D submode setting for cutter membrane delamination. Two different cutter settings for cutter membrane delamination can be switched and adjusted quickly and sequentially by a foot pedal control only

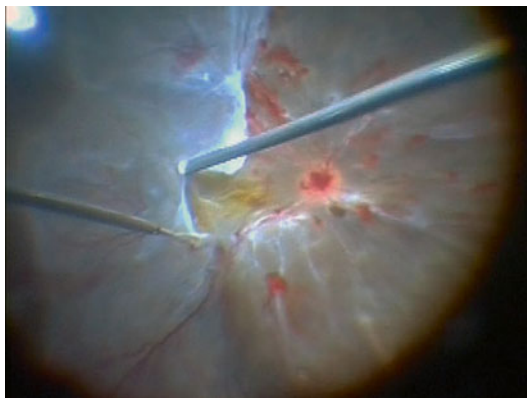

Fig. 14.11 Bimanual dissection of a fibrovascular membrane in diabetic cases. The membrane forceps allows us to grasp the edge of the membrane to easily introduce the blunt tip of the cutter into the tiny spaces between the detached retina and adherent membranes

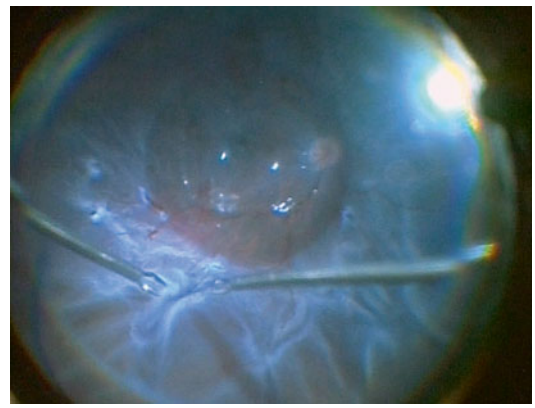

Fig. 14.12 Bimanual membrane peeling in cases with proliferative vitreoretinopathy. Using two forceps for peeling the strongly adherent membrane is a safe technique to avoid creating iatrogenic breaks

use of anti-VEGF drug is an effective option to minimize the chance of intraoperative bleeding, in case the bleeding occurs during membrane removal, the combination of a diathermy probe with a buck-flush needle or a cutter is a helpful strategy to find out the bleeding point by active aspiration with an immediate pinpoint hemostasis. Another option can be using the proportional reflux function to splash out the blood for the immediate pinpoint cauterization. Both techniques are very helpful to avoid the bleeding re-obscuring the bleeding point often seen during instruments exchange in the single-hand manipulation.

In PVR cases, using two forceps for peeling the strongly adherent membrane is a safe technique to avoid creating iatrogenic breaks (Fig. 14.12). It is also very useful to peel off the subretinal strands and/or membranes from a small intentional retinal hole with small-gauge instruments in a hand-to-hand manner to avoid enlarging the retinal hole. To visualize the transparent premature membranes, staining the membranes

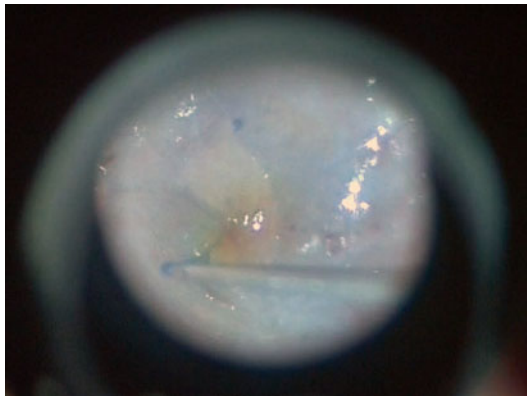

Fig. 14.13 Membrane peeling under perfluorocarbon liquid. Peeling off the membranes stained by BBG and trypan blue underneath perfluorocarbon liquid is a helpful technique to flatten and stabilize the detached retina for membrane peeling with small-gauge forceps

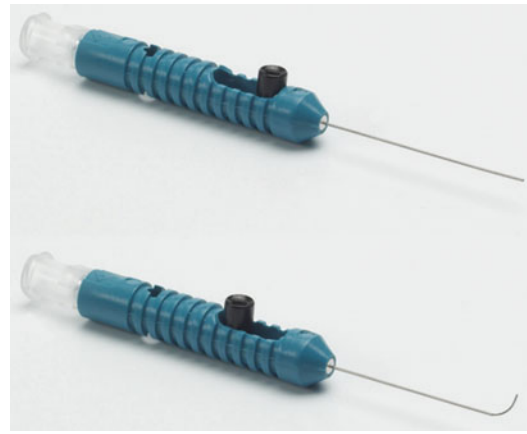

Fig. 14.14 25-g directional viscocannula for viscodelamination. The curvature and length of the inner cannula are adjustable and extendible by pulling the adjuster

with a solution of the mixed trypan blue and brilliant blue G (BBG) is a useful technique to concurrently visualize both preretinal membranes (by trypan blue) and internal limiting membrane (by BBG). Peeling off the membranes under perfluorocarbon liquid is also a helpful technique to flatten and stabilize the detached retina for membrane peeling with small-gauge forceps (Fig. 14.13).

14.3.3 Viscodelamination Technique

Viscodelamination is a well-known technique which had been reported in the 20-gauge era using a hydraulic force to separate the strongly adherent posterior hyaloid or premature fibrovascular membranes from the retina in diabetic cases [12]. The indication for this technique is limited to a small spectrum of case in which posterior vitreous detachment (PVD) has not occurred at all or is very localized if any. In addition, caution should be taken to avoid hydraulic force tearing the retina and misleading the viscoelastics into subretinal spaces. Nevertheless, it is a worthwhile technique for the above-described indicated cases to introduce or extend a focal PVD for subsequent maneuvers. Recently, a specially designed directional viscocannula has been commercially available from Synergetics, Inc., for 25- or 27-gauge small-gauge surgery

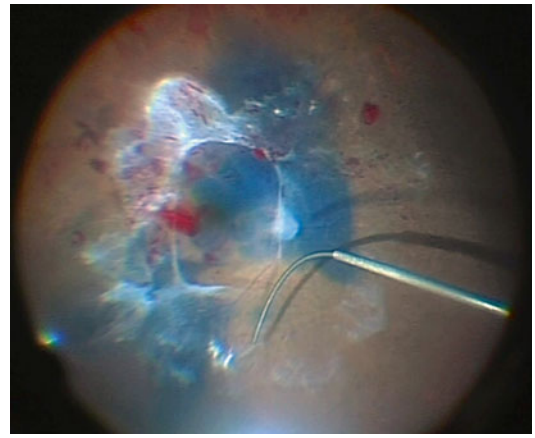

Fig. 14.15 The tip of the inner cannula can be inserted into the tiny spaces between the fibrovascular membrane and the retina. The areas where the posterior hyaloid detachment was created can be clearly visualized by the BBG-conjugated viscoelastics

(Fig. 14.14). The curvature of the inner cannula is adjustable and extendible. For viscodelamination, the inside-out approach is preferred over the outside-in approach described because the central retina is stronger than the retina outside the arcades. After creating a small approaching space around the disk area with a membrane pick, the tip of the extendible inner cannula can be easily inserted into the tiny spaces between the fibrovascular membrane and the retina. As shown in Fig. 14.15, I prefer injecting BBG-conjugated

viscoelastics for viscodelamination because it is easy to visualize the areas where PVD was created. Once an appropriate area of PVD is created, a transition back to the use of an ultrahigh-speed cutter is recommendable for subsequent membrane dissection.

14.4 Summary

The recent emerging surgical technologies and techniques in small-gauge vitrectomy appear to simplify surgical procedures, improve the safety and efficiency of surgery to reduce operating time, and lower the chances of encountering complications even in challenging cases such as diabetic tractional retinal detachment and PVR. The current state-of-the-art surgical techniques used with the high-end vitrectomy machines and wide-angle visualizing systems offer the best surgical options to use much smaller-gauge systems for even less invasive surgery in challenging cases.

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